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Dyscalculia/Specific Learning Difficulty in Mathematics: Identification and Intervention in Irish Primary Schools

Poor mathematical performance has often perplexed teachers. Low arithmetical attainment has varying causes including a general learning difficulty, a readiness lag, or a specific learning difficulty (SLD) in numeracy, also known as dyscalculia. This article presents the findings of a study of five Irish primary schools in relation to definitions, prevalence, causes and characteristics of SLD in numeracy. It also considers best practice for primary schools in assessment, identification and programme planning in relation to such difficulties.

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INTRODUCTION

Butterworth and Yeo (2004) describe dyscalculia as a "specific deficit of a very basic capacity for understanding numbers which leads to a range of difficulties in learning about number and arithmetic" (p. 1). The child with dyscalculia will present as being able to access other areas of the curriculum whilst struggling to access the mathematics curriculum. Geary (2004) suggests a prevalence of between five and eight percent. The causal components of dyscalculia are genetic and biological (Isaacs, Edmonds, Lucas and Gadian 2001; Shalev and Gross-Tsur, 2001). Children with dyscalculia are born without a 'number starter kit', "a capacity for recognising and mentally manipulating numerosities [the number of things in a set]" (Butterworth and Yeo, p. 1).

CHARACTERISTICS OF DYSCALCULIA

The identification of dyscalculia incorporates the elimination of possible causes of low attainment such as a general learning difficulty, a readiness lag, an inappropriate learning environment or the impact of other conditions on mathematical learning such as dyslexia. Familiarity with dyscalculia

characteristics may help the teacher to identify dyscalculia and provide appropriate intervention.

Counting

Young children with dyscalculia are unable to state the cardinality (number of objects) of sets up to five without counting (Butterworth and Yeo, 2004). Geary, Hamson and Hoard (2000) found that such children made more counting errors, reported counting errors less frequently (children observed a puppet count the first object in a set twice) and had not mastered the counting principle of order-irrelevance (objects can be counted in any sequence). Difficulties are encountered with number magnitude comparison (which number is bigger/smaller?) (Butterworth and Yeo, p. 3). Also, such children's perception of numbers as "small indistinct 'clumps of ones'," (Butterworth and Yeo, p. 7) signifies that these children find it difficult to see the relationship between numbers, thus the counting of groups of numbers is impeded. Hannell (2005, p. 14) notes that the child "has to recite the entire multiplication table to get to an answer".

Working Memory

A working memory deficit is an associative factor of dyscalculia (Geary, 1994; Butterworth and Yeo, 2004) which inhibits the development of counting, calculation and the establishment of basic number facts and procedures in long-term memory. Shalev and Gross Tsur (2001) claim that many manifestations of dyscalculia are age and grade related, stating that by nine to ten years of age, counting and number comparison have been mastered but inefficient number fact retrieval strategies are still employed.

Arithmetical Procedures

In the absence of automatic retrieval of number facts, strategies such as verbal and/or finger counting are employed. 'Counting-all' [5 + 3 is computed by counting from one to eight] is used "for several years beyond the point when most typically developing children have abandoned it in favour of 'counting on' [5 + 3 is computed by counting on from 5]" (Geary 1994, p. 158). Difficulties encountered during arithmetical procedures delay the procedural process. Such difficulties include writing two-digit numbers in reverse order, placing digits in the wrong column, taking the smaller numeral from the larger numeral regardless of its position (25 – 16: five is taken from six), confusing divisor and dividend in division or confusing operation signs such as '+' and 'x' (Hannell, 2005). The child may forget previously learned skills and cannot generalise acquired mathematical knowledge across several mathematical domains (Butterworth and Yeo, 2004).

IDENTIFICATION AND REMEDIATION OF DYSCALCULIA

The staged approach to intervention provides a framework for assessment, identification and programme planning in relation to pupils with special educational needs (Department of Education and Science (DES), 2005). Stage One incorporates screening by the class teacher to identify children with mathematical difficulties. If intervention by the class teacher is ineffective, additional diagnostic testing by learning support/resource (LS/R) teachers is recommended at Stage Two. Stage Three incorporates the referral of pupils, who have not progressed following supplementary teaching, to external supports such as psychologists.

Assessment

The National Council for Curriculum and Assessment (NCCA) (2007, p. 78) prioritises early identification and recommends that schools administer "group and individual tests of early literacy, numeracy and developmental skills by February of the second school year [senior infants]". The Learning Support Guidelines (DES, 2000) recommend early intervention (senior infants to second class), which is contingent upon early identification. Standardised attainment tests are used to screen older pupils (NCCA). Selection for LS/R teaching in mathematics prioritises pupils performing at or below the tenth percentile on standardised attainment tests (DES). However, results of standardised tests require cautious interpretation.

Low mathematical confidence, poor physical or emotional well-being and inadequate mathematical instruction or learning environment (Ginsburg, 1997) cause depressed scores on standardised attainment tests or cause performance to vary from year to year. Geary (2004) suggests that a lower than expected achievement score across successive years indicates a cognitive deficit in mathematics. This approach constitutes a 'wait to fail' model (Fuchs, Mock, Morgan and Young, 2003) and inhibits early intervention. Conversely, the componential nature (many mathematical domains within one test e.g. number, shape, and measurement) of standardised attainment tests may create an elevated score whereby poor performance on a particular aspect of mathematics is masked by the averaging of scores across several mathematical domains (Geary). An elevated score may deny access to LS/R teaching and inhibit the identification of dyscalculia, particularly according to the traditional identification method, whereby dyscalculia is evidenced by a discrepancy between achievement on standardised mathematics attainment tests and chronological age or measured intelligence. Rather than sole reliance on standardised testing as a means of

screening for children with mathematics difficulties, the NCCA (2007, p. 61) recommends "a range of assessment information" such as self-assessment, pupil portfolio, teacher observation and teacher-designed tasks and tests. Such assessment is also a useful tool for the measurement of a child's responsiveness to intervention and provides an opportunity to customise instruction in accordance with individual needs (Fuchs et. al., 2003). Consistent non-response to intervention could signify persistent dyscalculia (Shalev, Manor, Auerbach and Gross-Tsur, 1998).

Mathematics assessment should not merely inform the teacher of how the child compares to peers (Dowker, 2004). Identification of dyscalculia requires diagnostic assessment by the LS/R teacher regarding deficits associated with dyscalculia. In this respect, Geary et al. (2000) assessed counting, arithmetical procedures, fact retrieval, conceptual knowledge, working memory and speed of processing. They monitored verbal and finger counting and selection of 'count all' or 'count on' strategies because, "One can fail to diagnose dyscalculia when only accuracy is considered" (Butterworth and Yeo, 2004, p. 2). Observation of a pupil during assessment also enables the teacher "to ask him what he is thinking" (Henderson, 1998, p. 8). More precisely, the 'Dyscalculia Screener' (Butterworth, 2003) is a computer-based programme which indicates whether a child is at risk of presenting with dyscalculia. Chinn (2004) suggests interviewing children to elicit attitudes towards mathematics because low confidence and mathematics anxiety indicate and exacerbate dyscalculia (Emerson and Babtie, 2010).

Intervention Strategies

Following the identification of the individual needs of the child experiencing difficulties with mathematics, learning targets are formulated and implemented through planned intervention. Dowker (2004, p. 33) cites a longitudinal study by Denvir and Brown (1986), in which groups of six children "were taught mathematical skills which were regarded as 'next skills' up from their existing skills", the implication being that within the whole class context, group activities could be structured at varying levels of complexity to suit individual learning needs. Such a strategy builds on the child's acquired knowledge and is implemented through co-teaching and/or peer tutoring as recommended by the DES (DES, 2000; Department of Education and Skills, 2010).

The current emphasis on inclusion may lead to children with dyscalculia "receiving much of their instruction in mainstream classrooms rather than in resource rooms geared to better address their individual capabilities and specific disabilities" (Shalev and Gross-Tsur, 2001, p. 339). Innate difficulties with number facts recall

(Geary 1994; Geary et al., 2000; Shalev and Gross-Tsur) signify that children would benefit from intense intervention on basic number concepts rather than the delivery of the class curriculum with emphasis on number fact recall. The National Council for Special Education (NCSE) (2006) emphasises the importance of the Individual Education Plan (IEP). Also, the DES (2000) states that the class teacher has the responsibility of "adjusting the child's arithmetical programme in line with the agreed learning targets and activities on the pupil's Individual Profile" (p. 42). A situation may arise whereby a child with dyscalculia, who is withdrawn for arithmetical support, works with two separate mathematics programmes (LS/R programme and class programme). Dual work programmes inhibit opportunities for repeated practice and generalisation, which develop competence, a vital component of mathematical confidence (Hannell, 2005).

METHODOLOGY

The research objectives of this study were to:

- Investigate teachers' familiarity with the term 'dyscalculia'
- Describe current screening procedures by class teachers for referral to LS/R teaching in mathematics
- Establish current diagnostic procedures used by LS/R teachers
- Explore the most commonly used interventions by class teachers and LS/R teachers
- Report on measurement of responsiveness to intervention
- Ascertain teachers' needs in relation to teaching children with an SLD in mathematics.

Research Design and Context

The research incorporated a non-experimental design, using quantitative and qualitative approaches. A convenience sample of five Dublin schools in the same geographical area was employed which could eliminate socio-economic disparity as a variable in the study. The sample represented single sex and co-educational schools. Questionnaires followed by semi-structured interviews explored current practice in the identification and assessment of children with mathematical difficulties and explored interventions for these children. Following piloting of the questionnaire, two sets of questionnaires were distributed. Teachers from senior infants to sixth class completed a Classroom Teacher Questionnaire and LS/R teachers completed a slightly amended version of that questionnaire, thus providing two perspectives. A Likert scale was used to compile data regarding frequency of use of screening and diagnostic assessment and interventions (1 = not at all, 2 = very

little, 3 = a moderate amount, 4 = quite a lot, 5 = a very great deal). Four semi-structured interviews were conducted based on data derived from questionnaire findings. Interviewees were drawn from the sample of quantitative respondents. The interviewees were two LS/R teachers, and two class teachers from two of the five schools. Questionnaires were distributed to eighty-two class teachers and twenty-two LS/R teachers. Completed questionnaires were received from fifty-seven class teachers and fifteen LS/R teachers, a total of seventy-two respondents. Quantitative questionnaire data were analysed by the Statistical Package for the Social Sciences (PASW/SPSS) statistics programme. Qualitative data from the questionnaires and interviews were transcribed and coded thematically.

Limitations of Study

Findings from this study cannot be easily generalised due to convenience sampling and the fact that participants were based in the same geographical area. The low number of LS/R teachers in the study impeded SPSS analysis. Use of the term 'dyscalculia' was inhibited in the questionnaire due to unfamiliarity with the term and therefore reports of interventions related globally to 'children experiencing difficulties with mathematics'.

RESEARCH FINDINGS

Table 1: LS/R Frequencies of pupils attending mathematics LS/R

Class	No. of Classes	Total no. of Pupils	Mean Class Size	No. of Pupils in LS/R	% of pupils in LS/R (rounded up)	% of class level (rounded up)	Mean no. of pupils in LS/R per class
Senior Infants	8	223	28	2	1	1	0.25
First	9	254	28	18	13	7	2.00
Second	7	183	26	20	14	11	2.85
Third	8	227	28	32	23	14	4.00
Fourth	9	263	30	34	24	13	3.77
Fifth	7	207	30	11	8	5	1.57
Sixth	9	246	27	24	17	10	2.66
Total	**57**	**1603**	**28**	**141**	**100**	**9**	**2.47**

Number of Children Receiving LS/R Support in Mathematics
Senior infant teachers reported the lowest proportion of children receiving support. Children from third to sixth class accounted for seventy-two percent (n = 101) of those receiving LS/R (n = 141). Overall nine percent (n = 141) of the total number of pupils (n = 1603) were receiving additional support in mathematics. Table 1 illustrates the frequency of each class level and numbers of pupils attending LS/R in mathematics.

Teachers' Familiarity with Dyscalculia
Just over half the teachers surveyed (fifty-five percent, n = 40) were familiar with the term 'dyscalculia'. A higher proportion of LS/R teachers (eighty percent, n = 12) than class teachers (forty-nine percent, n = 28) reported familiarity with the term 'dyscalculia'. A Chi-square test on the association between teacher type and familiarity with the term 'dyscalculia' yielded statistically significant results ($x2 = 4.59$, d.f. = 1, $p = .03$). The questionnaire revealed that twelve percent (five class teachers and four LS/R teachers) reported receipt of in-service training in relation to SLD in mathematics.

Screening and Diagnostic Procedures
Teachers in the study were presented with a range of screening and diagnostic assessment options and indicated their use of these instruments by means of a Likert scale. Standardised attainment tests and observation were the most frequently used methods for referral to LS/R for 'maths help' from first to sixth class. Pupil portfolio and error analysis were the least used methods. Senior infant teachers relied mainly on observation as a screening instrument. Interview data revealed cut-off points for referral to LS/R at the twenty-fifth percentile and below.

A range of diagnostic testing was implemented by LS/R teachers in the study. The most frequently used strategy was 'asking how the pupil got the answer', followed by observation of procedural competence, number fact recall and number comparison. Mean scores indicate that counting on/all and finger/verbal counting was observed 'quite a lot' which indicates diagnostic observation by LS/R teachers of some deficits associated with dyscalculia. Assessment of working memory and interviews to establish pupil attitude toward mathematics, two key indicators of dyscalculia, occurred less frequently.

LS/R teachers were asked to specify any standardised diagnostic tests employed at Stage Two. Almost half (forty-six percent) LS/R teachers cited standardised attainment tests (screening instruments) in this questionnaire item. Five LS/R

teachers did not complete this questionnaire item. Twenty percent (n=3) of the LS/R teachers in the study cited the use of a standardised diagnostic test. These results seem to indicate a trend towards informal diagnostic assessment. Qualitative questionnaire data from one LS/R respondent revealed "lack of knowledge of assessment/diagnostic tests".

Method of Support

Results indicate that fifty-seven percent (n = 27) of class teachers reported in-class only or combined in-class and withdrawal support. With regard to in-class support, one LS/R interviewee commented that, "Sometimes the pace is very fast for children who are weaker...they are actually making progress...and next thing they have moved on...It's very hard to let the child feel some sort of sense of achievement". The highest proportion of teachers who reported withdrawal-only was from fifth/sixth class (fifty percent, n = 8).

Strategies

The most frequently reported strategies with children experiencing mathematics difficulties were: teacher demonstration, whole-class instruction and individualised instruction. Peer tutoring and co-teaching were the least cited strategies. Mean scores for group instruction increased from senior infants to fifth/sixth class, possibly a consequence of the emergence of differing levels of mathematical attainment and LS/R support within the classroom.

Content

Teachers in the study indicated their use of a range of mathematical learning content options by means of a Likert scale. The participants reported most frequent use of number fact recall, foundation numeracy skills and class curriculum. Recall of number facts was prioritised from third to sixth class. Teachers from fourth to sixth class and LS/R teachers reported an overall mean of 2.98 (3 = 'a moderate amount') for calculator use. However, LS/R teachers placed less emphasis on the learning of number facts. More LS/R teachers (ninety-three percent, n = 14) than class teachers (fifty-nine percent, n = 30) used IEPs from 'a moderate amount' to 'a very great deal'. Mean scores indicate a shift from class curriculum to dual programmes, foundation numeracy and IEP use in fifth/sixth class, perhaps because a greater proportion of fifth/sixth class teachers cited withdrawal support. Cross-tabulation shows that of class teachers whose pupils were withdrawn for LS/R in mathematics, ninety percent, (n = 18) used dual work programmes (LS/R programme and class programme) from 'a moderate amount' to 'a very great deal'. Chi-square tests yielded statistically significant results ($x^2 = 8.04$, d.f. = 1, $p < .01$).

Progress Measurement

Class teachers (seventy-nine percent, n = 45) and LS/R teachers (eighty percent, n = 12) reported monitoring progress. Observation within the classroom and teacher-designed tests were cited most frequently, therefore progress measurement appears embedded within the class curriculum. IEPs were the least used progress measurement instruments.

Teachers' Needs

An open-ended questionnaire item asked all respondents to describe their needs in relation to teaching children with SLD in mathematics. This theme was further explored during interviews. Teachers reported a need for in-service regarding indicators of SLD in mathematics, assessment and intervention because, as one interviewee observed, "It's very important that teachers would have...a whole broader knowledge of dyscalculia and different approaches". Teachers described time and class size as barriers to planning and differentiation. Questionnaire data highlighted difficulties such as, "Taking time to teach and clarify and assess understanding of weak pupils and keep rest of class challenged and engaged". Class teachers reported the need for early identification and early LS/R intervention.

DISCUSSION AND CONCLUSION

Referral to LS/R Teacher

A range of screening instruments were employed by class teachers. However, infant teachers reported sole reliance on class teacher observation, with little consultation with the LS/R teacher. Reliance on the results of standardised attainment tests both for screening and diagnostic assessment was evident in the sample studied, despite possible difficulties associated with the interpretation of pupil performance on standardised attainment tests. The reported cut-off points of up to the twenty-fifth percentile are also found in Geary et al. (2000), signifying that elevated scores would not deny children with dyscalculia access to LS/R provision. Questionnaire data revealed an average of 2.47 children per class in receipt of maths support (Table 1). This is less than ten percent (class size ranged from 27 to 30 pupils), inferring that less than ten percent of pupils in the participating schools attained the twenty-fifth percentile or below on standardised attainment tests. Lack of SLD in-service training and unfamiliarity with the term 'dyscalculia', indicate that many class teachers are unaware of dyscalculia indicators during the screening process, perhaps accounting for the less frequent use of error analysis and pupil portfolio, useful tools for analysis of mathematical difficulties (Dowker, 2004; NCCA, 2007).

Diagnostic Assessment

Despite unfamiliarity with standardised diagnostic tests such as the 'Dyscalculia Screener' (Butterworth, 2003), a variety of indicators were assessed by LS/R teachers, mainly through observation conducted during the mathematics lesson. However, diagnostic observation conducted against the backdrop of a cumulative class curriculum may not assist analysis of the specific origin of a mathematical difficulty. Contrary to Geary et al. (2000) and Chinn (2004) respectively, key indicators of dyscalculia such as working memory and attitude towards mathematics were assessed very little by the participants in this study.

Intervention

Reported proportions of pupils receiving LS/R seem weighted in favour of class levels from third to sixth, which is contrary to DES (2000) recommendations regarding early intervention. This may relate to standardised testing from first to sixth class and it could also be perceived as adherent to Stage One (DES, 2005), whereby class teachers are in the process of providing additional intervention and have yet to analyse pupil response to intervention.

The assumption cannot be made that all children receiving mathematics LS/R teaching have dyscalculia. Some children may benefit from the reported interventions. Results indicated commendable provision for children with mathematical difficulties; however unfamiliarity with dyscalculia may result in provision which is not specific to, or does not fully address specific deficits. Hannell's (2005) assertion that dyscalculia is present in two or three children per class signifies that out of fifty-seven classes in the sample, at least 114 children are likely to present with dyscalculia. A 'keep up' with the class curriculum approach, as results from the sample indicate, may lead to increased withdrawal-type support and a separate classroom programme in senior classes. The reported frequent use of foundation numeracy teaching by LS/R teachers in senior classes implies that some children are unable to access the cumulative mathematics curriculum whilst also being denied opportunities within the classroom to practice and overlearn foundation skills acquired in LS/R, which foster competence and confidence (Hannell).

Emphasis on the class curriculum signifies that progress is more likely measured with reference to class targets rather than to IEPs. This impedes measurement of the child's response to a particular intervention, a significant criterion in the identification of persistent dyscalculia.

RECOMMENDATIONS

Within the classroom, unfamiliarity with dyscalculia may lead to unrealistic expectations with regard to accessing the class curriculum and number fact recall. Teachers expressed the need for in-service training regarding SLD in mathematics in order to assess deficits associated with dyscalculia such as working memory and attitude towards mathematics, through the use of pupil portfolios, error analysis, pupil interviews and standardised diagnostic tests in order to facilitate early intervention for the child with dyscalculia. Early intervention for these children is of utmost importance and could consist of withdrawal support as recommended by Shalev and Gross-Tsur (2001) due to the cumulative nature of the mathematics curriculum and a basic number skills deficit associated with dyscalculia.

Rather than dual work programmes, perhaps an interactive approach might be used. Strategies and individual learning targets, formulated with reference to the inherent mathematical difficulties associated with dyscalculia and implemented both in classroom and LS/R settings, would enhance the child's progress in arithmetic. Class teachers in this study were experienced in the utilisation of group work. Further development of this skill through in-service training in co-teaching, differentiated group work and peer tutoring, in conjunction with LS/R support, would assist teachers in providing for differing needs within the class.

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