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Supporting children with mathematics learning difficulties: Outcomes of an intervention program

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Abstract

At least 20% of adults have very low numeracy (Bynner & Parsons, 1997) and about 5-8% of the population has severe specific Mathematical Learning Disabilities (Butterworth, Varma & Laurillard, 2011). Failure to acquire basic mathematical skills may have serious life-long consequences. Thus, it is important to find ways of enabling children with MLD to acquire numeracy skills. The present study involved 10 children in Grade 3 (7 to 8 years old), identified by their teachers as struggling with mathematics. They were assessed using the Dynamo Assessment, which provides a profile of strengths and weaknesses in important components of mathematics. Five children acted as controls, while the other five followed the Dynamo Intervention programme. The intervention lasted for eight weeks. All the children were subsequently re-assessed using Dynamo Assessment. The profiles of the children who had undergone intervention showed improvement in most components, while the control group did not.

Keywords: Mathematical learning difficulties,grade 3,Dynamo Intervention,Dynamo Assessment.

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1. Introduction

It has been estimated that approximately 6% of a population has developmental dyscalculia (Butterworth, Varma & Laurillard, 2011). Since an exact definition specifying the nature and degree of this specific learning difficulty is not yet available, it is presumed that if higher cut-off points are used in studies, many more individuals would result in having severe numeracy difficulties that persist into adulthood. As a result, a study carried out by Parsons & Bynner (2005) reported that about 22% of a large sample of British adults had numeracy difficulties severe enough to cause serious practical and economic problems. Hence the need for a deeper insight into the nature and degree of mathematical learning difficulties (MLD) is fundamental as is a better understanding of effective intervention strategies that support individuals in overcoming their difficulties with mathematics. This study emerges from this necessity.

This research had two main aims. Primarily it sought to investigate whether the participants in the intervention group make any improvement in the components of mathematics assessed by the Dynamo Assessment following an eight week intervention programme using Dynamo Intervention. Their progress was compared to the Control group which did not participate in the intervention to see whether any differences were evident. Moreover it aimed to investigate whether some components were more susceptible to intervention than others.

2. Literature Review

Difficulties in arithmetic are common. There are debates as to what constitutes mathematical disability: in particular, how specific, severe and persistent such difficulties must be, and how strict the criteria should be for specificity, severity and persistence (Desoete, Roeyers & DeClerq, 2004; Gifford & Rockcliffe, 2008; Mazzocco & Myers, 2003). The commonest estimate, backed up by evidence from several countries, is that about 6% of children have severe specific difficulties with arithmetic (Butterworth et al., 2011; Bzufka, Hein & Neumarker, 2000; Geary & Hoard, 2005; Gross-Tsur, Manor, & Shalev, 1996; Reigosa-Crespo et al., 2012). A far higher number of individuals have mathematical difficulties that are less severe or less specific, but which still have very serious effects on children's education and which frequently persist into adult life, with severe social, occupational and functional consequences. A large-scale study in the UK suggested that 22% of adults have such numeracy difficulties (Bynner & Parsons 1997; Parsons & Bynner 2005). There have been no comparable studies in Malta, but low mathematical attainment appears to be a common problem there.

There is a strong association between early and later mathematical difficulties. For example, Bynner & Parsons (1997) found that most of the adults with serious numeracy difficulties had already shown difficulty with mathematics by the age of seven. Therefore, successful early intervention with children, who have difficulties with mathematics, could have very important implications for their functioning as adolescents and adults.

Evidence from behavioral studies, educational studies and neuroscience converges strongly on the conclusion that arithmetical ability is not unitary, but is made up of many different components (Dowker, 2005, 2015). These may be grouped into several categories (e.g. procedural, factual and conceptual); but each of the categories has numerous subcomponents. Moreover, no two children (or adults) with arithmetical difficulties are the same (Dowker, 2005; Dowker & Sigley, 2010). It is important to find out what specific strengths and weaknesses an individual child has; and to investigate particular misconceptions and incorrect strategies that they may have.

Such targeted interventions for children who are low-attaining in mathematics include very intensive programs for children with severe difficulties, such as Mathematics Recovery (Wright, Martland & Stafford 2006) and Numbers Count (Dunn, Matthews & Dowrick 2010; Torgerson, Wiggins, Torgerson et al, 2011). For children with somewhat less severe but still significant difficulties, they include the lighter-touch programme of the Catch Up® Numeracy intervention, which was developed by Dowker in collaboration with the Catch Up® Trust, a not-for-profit UK registered charity (Dowker & Sigley, 2010; Holmes & Dowker, 2013). Children in the programme receive interventions from trained teachers or teaching assistants during two 15 minute sessions per week. Initially, each child is assessed individually on each of ten Catch Up Numeracy components and the appropriate focus for numeracy teaching. They are provided with mathematical games and activities targeted to their specific levels in specific activities. Children given this intervention were found to gain more than twice as much in mathematics age as would be expected by the passage of time alone, and very significantly more than children given no intervention beyond their usual schooling, or given matched-time non-targeted intervention (Holmes & Dowker, 2013). Thus, the study supports the view that targeted interventions are likely to be particularly effective.

The focus of the present study is another, recently developed targeted intervention: Dynamo Maths. This includes assessment and intervention in 9 components relating to fundamental numerical abilities and thought to be related to dyscalculia, and 6 more relating to school-taught abilities.

3. Research design

Since the nature of the data needed to answer the research questions was of a descriptive type, qualitative research methods were deemed more appropriate. The research had a pre-assessment phase in which all participants were assessed, an eight week intervention phase in which the Intervention Group (IG) received the intervention on a one-to-one basis and a post-assessment phase in which all participants were assessed once again. Ethical considerations unpinned each phase and it was ensured that consent was always voluntary. Permission to carry out the study was not only obtained from the authorities governing the school but also from the parents of the pupils as well as the pupils themselves. The participants' confidentiality and privacy were safeguarded throughout even in this presentation of the findings. Moreover, due to ethical issues, the Control Group (CG) was promised to receive the same intervention once the data had been collected.

3.1. Sample

It was decided that Grade 3 (7 to 8 year olds) would be the best participants for this study. Grade 3 level is generally where the teaching and learning of mathematics starts to become more formal and thus difficulties in mathematics start to become more apparent. This age group was also most suitable because the intervention programme used in this study caters mainly for learners ages 6 to 9. The sample was selected from the same Church school for boys in Malta. This was practicable (Cohen, Manion & Morrison, 2007) since one of the researchers worked at the same school but also deemed necessary since this would limit variables and ensure that data collected was more valid and reliable. Following discussions with the two Grade 3 classroom teachers, 4 participants were chosen as the IG and another four were selected as the CG. All efforts were made to match the profiles of the learners within the IG group to those of the CG as closely as possible.

3.2. Pre- and post-assessment

All the participants were assessed before and after the intervention phase using the Dynamo Assessment. Dynamo Assessment is a computer based assessment that takes into account the componential nature of mathematics. It has been developed on a NumberSenseMMR™ Framework. Dynamo Assessment identifies the mathematical components which the children would be struggling with so that this detailed profile may be used for intervention. The Dynamo Assessment supports the argument that there is no such thing as mathematical ability but rather mathematical abilities (Dowker, 2005) because rather than being quantitative in nature and drawing a conclusion as to whether a child is good or bad at mathematics it explores the learner's profile in depth and provides a good foundation for intervention. Moreover, it also indicates whether the difficulties encountered by the child are symptoms related to dyscalculia or whether they are evidence of mathematical developmental delay. A sample of the first part of the Assessment, outlining the 15 components of mathematics assessed by the Assessment can be seen in Figure 3.1.

Following the initial profile presented, Dynamo Assessment identifies the parts of Dynamo

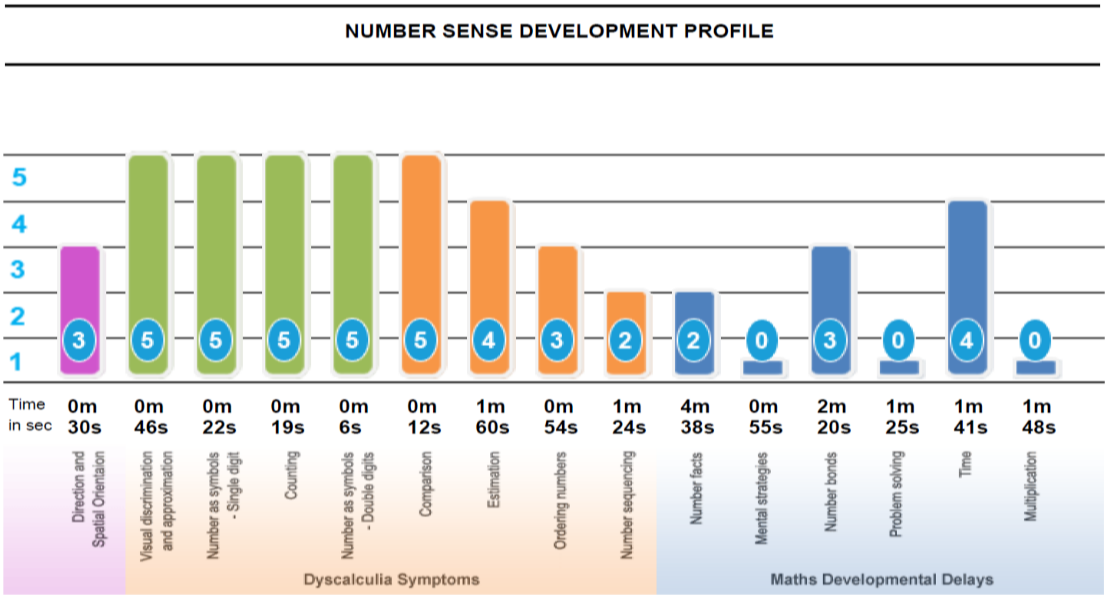

Figure 1 Part of the Dynamo Assessment

Intervention which should be followed and additional activities to cater for the difficulties being experienced by the child. All the participants sat for the Assessment on a one-to-one basis. This was important because the assessment also recommends that the assessor takes note of any observations which the computer would not have been able to pick up on.

3.3. Intervention phase

The Intervention with the IG took place over an 8 week period and took place using Dynamo Intervention. Intervention sessions took place for 15 minutes daily. Nonetheless due to school activities and/or holidays, the participants inevitably missed some of the sessions – this amounted to approximately seven sessions across the weeks. All intervention took place on a one-to-one basis. It was carried out during school hours whilst the other children in class were doing mathematics lessons or extracurricular lessons. Each intervention programme was tailored made as instructed by the Dynamo Assessment to suit the individual profile of the learners. Dynamo Intervention can be accessed online and is composed of four Dynamos (categories) encompassing the different components of mathematical difficulties which might be identified by the Assessment. Dynamo 1 and Dynamo 2 focus on number sense whilst Dynamo 3 and 4 focus on number proficiency. Each Dynamo has a number of modules. Every module has associated lesson plans, worksheets and on-line activities for the adult working with the learner to make use of. The performance of each learner on the online activities is recorded and one can view the number of times an activity was tried out by the child and their performance in each. Moreover, it is suggested that the adult carrying out the intervention keeps note of any observations carried out whilst working with the learner on the various lesson activities provided or whilst watching the learner complete the worksheets provided.

4. Findings

The results on the pre-assessment and post-assessment of the participants have been analyzed both quantitatively, and more importantly qualitatively. Upon analyzing the difference between the pre-assessment scores and post-assessment score of the IG versus the CG, it was noted that the IG showed a greater improvement in the scores obtained. ANOVAs with Group as the main factor (Control vs Intervention) and Pre-test score, Post-test score and Improvement as the dependent variables showed no significant effect for the combined dyscalculia-related abilities. For the combined school mathematics components ANOVAs with Group as the main factor (Control vs Intervention) and Pre-test score, Post-test score and Improvement as the dependent variables showed no significant effect of Group on Pre-test score (showing that the children were performing similarly at the start), but significant effects of Group on Post-test score ($F(1,8) = 7.956$; $p = 0.022$) and on Improvement ($F(1,8) = 17.194$; $p = 0.003$). For the combined scores for all 15 components together, ANOVAs with Group as the main factor (Control vs Intervention) and Pre-test score, Post-test score and Improvement as the dependent variables showed no significant effect of Group on Pre-test score (showing that the groups did not differ at the outset), but significant effects of Group on Post-test score ($F(1,8) = 7.005$; $p = 0.029$) and on Improvement ($F(1,8) = 16.177$; $p = 0.004$).

Thus, the statistical analysis carried out indicated that the intervention group improved very significantly more than the control group on the tests of mathematical weakness, and overall. Improvement did not reach significance for the dyscalculia items. This could mean that these are less susceptible to intervention, or could indicate a ceiling effect: most of these children showed far fewer problems on these items than on the mathematical weakness items. Nonetheless, more participants are needed to draw firm conclusions thus the qualitative analysis carried out was important for identifying characteristics of this improvement which may shed light on which strategies are most effective when working with children with MLD.

Primary observations of the Assessments of all the learners highlight the reality that there is nothing like mathematical ability but rather mathematical abilities (Dowker, 2005). The Assessments illustrated how although all the participants could be identified as learners struggling with mathematics, all their profiles demonstrated a different combination of strengths and weaknesses. Moreover a qualitative analysis of the profiles of the IG and the CG in both phases of the assessment evidently showed that the IG demonstrated improvement in most components, whilst the CG made less progress. It was also noted that whereas for the IG little regression was recorded in their mathematical abilities at post-assessment phase, this was not the case with the CG since regression seemed more common possibly due to the lack of making use of these specific abilities. The profiles (pre-assessment and post-assessment of a pupil from the IG can be seen in Figure 4.1 whilst the pre-assessment and post-assessment of that pupil's counterpart within the CG can be seen in Figure 4.2. Discrepancies can evidently be noted.

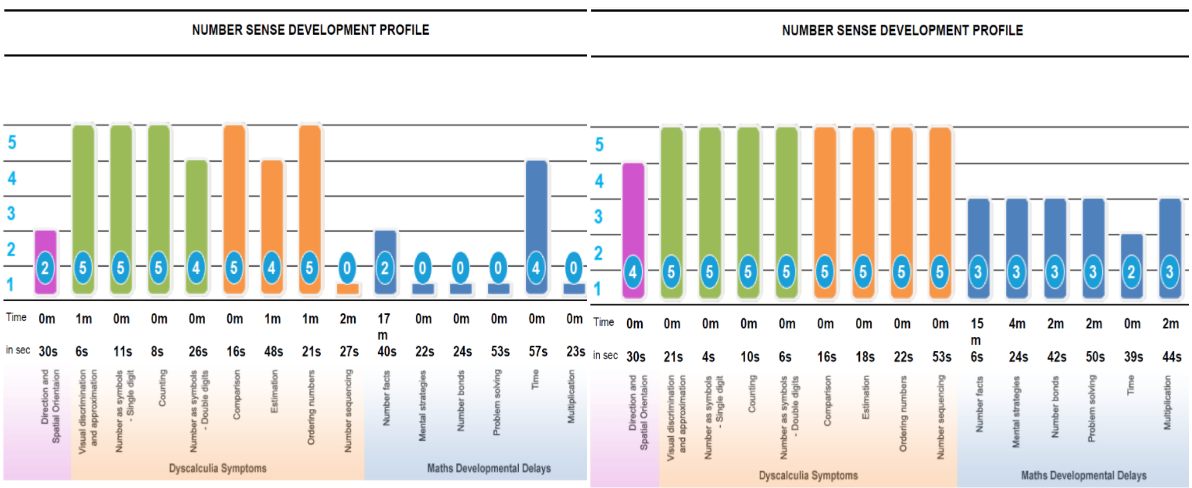

Figure 2 Pre-assessment and Post-assessment for participant in IG.

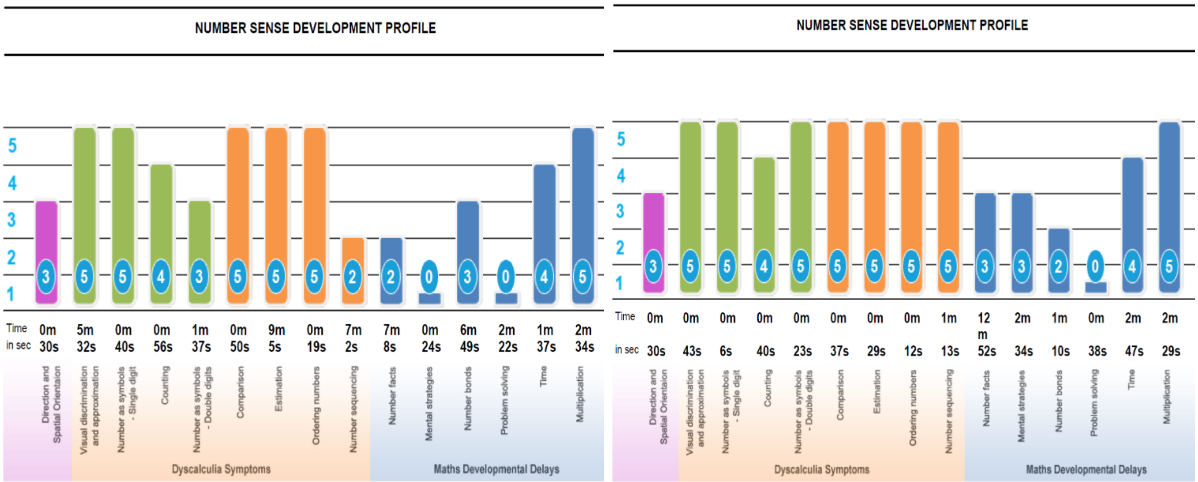

Figure 3 Pre-assessment and Post-assessment for participant in CG.

These are only two examples however the other participants in the IG had similar positive results. In addition, it was observed that for most of the IG Dynamo Intervention had a positive impact on the Dyscalculia symptoms highlighted by the Assessment. This shows that these symptoms can be malleable and can be positively improved, even though our statistical analysis of the data has indicated that progress may be limited. Moreover, similar to the findings from other studies (Kaufmann, Handl & Thony, 2003; Holmes & Dowker, 2013), these results evidently illustrate that learners with MLD who receive the right form of intervention may make desired progress in most, if not all, areas of mathematics learning. It has also been illuminating to note that since the areas indicated as those related to dyscalculia were addressed these seemed to have a positive effect on other components including multiplication, problem solving and number bonds. This because even though these were not targeted directly during the intervention sessions (due to a lack of time), the children's abilities in them showed progress in the post-test. This supports the argument that mathematics has a componential nature (Dowker & Sigley, 2010) and thus that specifically targeting one component at a time can not only scaffold the progression in the targeted components but also in a number of other components.

The researchers have analyzed why Dynamo Intervention has been effective as an intervention programme in an attempt to shed light on which strategies are effective with learners having MLD. Primarily it should be highlighted that the intervention programme embraces scaffolding (Bruner, 1978) and thus all lesson plans, worksheets and online activities are scaffolded both in the of content and the ways in which they are presented. Moreover a multisensory approach to the learning of mathematics is promoted in all the lesson plans. The lessons are built around giving the learner the image and context as well as the symbols for a specific component. These aspects of teaching mathematics have been identified as paramount (Haylock and Cockburn, 2013). The different modes of delivering learning ensure that learners with different learning styles grasp the concepts and skills at hand. The digital activities are very attractive for the learner. They not only praise the learners for the successful completion of a task but also illustrate why the answer is wrong when this is the case. The learners seemed very enthusiastic about doing the digit activities and many times kept trying the activity until they managed to get a 100% on the task. It is thus valuable that the programme records the number of times a task would have been tried out and the progress of the learner in each task. The possibility to follow up on what has been covered during school time at home is also highly beneficial and supports the learners in gaining mastery of the topics.

An interesting observation has been that the attitudes towards mathematics as identifies by each of the pupils whilst being assessed using the Dynamo Assessment did not seem to be effected by the intervention. Children who said they "enjoyed maths" or "found maths hard" at the beginning of the intervention programme maintained the same view of mathematics. This observation was also made in respect of the CG. This may have occurred because the intervention programme was rather short and may indicate that for attitudes to change the intervention needs to be carried out on a longer time span. Attitudes form part of the affective domain of learning (Ernest, 2011). From the results of this one study one may conjecture that cognitive mathematical abilities may indeed be more easily malleable than attitudes and beliefs about mathematics that form part of the affective domain.

5. Conclusion

The assessments carried out as part of this study have supported the argument that children MLD normally exhibit difficulties with specific components of mathematics and not all components. Moreover, the actual intervention and post-assessment have indicated that children with MLD have a greater possibility to make marked progress when their mathematical difficulties are targeted specifically in a scaffolded manner. It has been suggested that Dynamo Intervention has been an effective intervention programme for the participants in this study because it provides a multisensory approach to the teaching of mathematics and provides a triangulation of teaching strategies including one-to-one teaching activities, worksheets and on-line activities. Dynamo Assessment and Dynamo Intervention illustrate how technology can be used as an effective tool to support children with mathematics learning difficulties since it can be accurate and specific in its assessment and intervention. Nonetheless the results obtained in this study as due to a balanced intervention approach which is not only based on the online modules but also on providing multisensory learning experiences through the teaching activities proposed and the paper work suggested. The results of the research seem to indicate that the input of all forms of strategies are indispensable for learners to make much desired progress.

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