Effectiveness of Number Masters© in improving children's number skills in Key Stage 1

VAUXHALL PRIMARY SCHOOL

The Oval Learning Cluster

NumberMasters©

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Introduction

The 2014 National Curriculum for England (Mathematics programme) explicitly states the requirement for schools to ensure pupils achieve computational fluency through their primary schooling. The programme of study for mathematics makes clear in its aims that pupils should "become fluent in the fundamentals of mathematics, including through varied and frequent practice with increasingly complex problems over time, so that pupils develop conceptual understanding and the ability to recall and apply knowledge rapidly and accurately."

Fundamental to this rapid and accurate recall of mathematical knowledge is the acquisition of computational fluency and automaticity.
Below is an extract from "Developing Number Fluency - What, Why and How," an article published by NRICH:

What is fluency?
The first thing to say is that fluency is not only about number – there are other areas of the curriculum where fluency is important. However it's probably sensible to acknowledge that number is by far the largest part of the primary curriculum, so in this article we'll concentrate on that. We're not the only nation to take a recent interest in this – in the US the new standards have quite a lot to say about being fluent:

Students exhibit computational fluency when they demonstrate flexibility in the computational methods they choose, understand and can explain these methods, and produce accurate answers efficiently.

Russell (2000) spells this out in more detail and suggests that fluency consists of three elements:

Efficiency - this implies that children do not get bogged down in too many steps or lose track of the logic of the strategy. An efficient strategy is one that the student can carry out easily, keeping track of sub-problems and making use of intermediate results to solve the problem.

Accuracy depends on several aspects of the problem-solving process, among them careful recording, knowledge of number facts and other important number relationships, and double-checking results.

Flexibility requires the knowledge of more than one approach to solving a particular kind of problem, such as two-digit multiplication. Students need to be flexible in order to choose an appropriate strategy for the numbers involved, and also be able to use one method to solve a problem and another method to check the results.

So fluency demands more of students than memorising a single procedure – they need to understand *why* they are doing what they are doing and *know when it is appropriate* to use different methods.

Taking these in consideration therefore, Vauxhall Primary School and the Oval Learning Cluster developed a programme called **Number Masters©.**

Number Masters© is a unique two-year programme created by mathematics teachers in the Oval Cluster (a cluster of nine primary schools in Lambeth), led by Vauxhall Primary School, aimed at the development of number mastery and computational fluency in Key Stage 1. The number and calculation skills covered are taken from the 2014 National Curriculum for Mathematics. We have maximised the expertise of the co-writers/practitioners to ensure that mastery is achieved at the end of each unit through practical, easy to plan, engaging, and age-relevant activities.

Each lesson in the **Number Masters©**programme is designed to be taught to a small group of pupils, maximum of 8, by a class teacher or teaching assistant, for 15-20 minutes a day, five days a week. This is to ensure that children's engagement with numbers is intensive and consistent, with the proven effectiveness of small-group work, using scripted materials. Assessment activities are planned for at the end of each week.

The key features of the Number Masters©programme are:

- Lessons, designed by teachers for teachers, are aimed at achieving mastery and computational fluency by focusing on fewer lessons for a longer time.
- Proven effectiveness of small- group work using scripted materials
- Practical activities using resources that are mostly available in schools, requiring minimal preparation time.
- Fulfils the requirements of the 2014 National Mathematics curriculum for Key Stage 1.

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Review of Related Literature

Computational Fluency. Numbers skills and computational fluency are common terms found in many primary curricula in various countries. In defining this aspect of mathematics, curriculum designers refer to fluency as not simply about computational drills without attributing meaning to operations. In contrast, it is about learning basic facts with a focus on "developing and using mathematical strategies, with the goal of finding efficient, effective ways to apply known facts to derive unknown facts" (Kling, 2011). Research indicates that children who are fluent in basic arithmetic facts tend to perform better in complex mathematical tasks (Skinner, Fletcher, & Hennington, 1996). In addition, lack of fluency was found to be related to students' mathematics anxiety (Cates & Rhymer, 2003). In this sense, pupils' fluency in arithmetic deserves a careful attention and monitoring in schools. On the other hand, fluency is not a skill that needs to be mastered in an extended time period and requires long term programs spread over the entire school year.

Recent research on computational fluency establishes rapid and automatic recall of number facts as a pre-condition for pupils' development of higher-order maths skills. This, as research suggests, is based on the premise that all human beings have a limited information-processing capacity and that simply put, an individual can only attend to a limited number of tasks at any given time. The impact of this on the development of mathematics was made explicit by Whitehurst (2003): "Cognitive psychologists have discovered that humans have fixed limits on the attention and memory that can be used to solve problems. One way around these limits is to have certain components of a task to become so routine and over-learned that they become automatic."

Automaticity. Number Masters© aim to address this by ensuring that children achieve automaticity when retrieving basic facts. This is addressed in the programme by covering fewer objectives for an extended period of time. Successful development of automaticity and computational fluency will enable pupils to develop high-order mathematics skills involving complex, multi-step computations. Studies show that underdeveloped fluency retrieval severely impairs pupils' further computational skills (Resnick, 1983), and even the development of everyday life skills (Loveless, 2003). Highly developed math-fact retrieval has also been shown to be a strong predictor of performance on mathematics achievement (Royer, Tronsky, Chan, Jackson, & Merchant, 1999.)

Mastery Learning. Number Masters© is very much aligned to the concept of the mastery learning approach in mathematics. Several studies show that when teachers emphasise mastery approach goals the norms and values in the classroom encourage learners on-tasks behaviour and discourage their anxiety and disruptive behaviour, foster long-term learning strategy usage, help students to create realistic and challenging goals, and instil a belief that effort is tied to success (Ames & Archer, 1988; Kaplan, Gheen, and Midgley, 2002). Similar studies show that when mastery goals form part of classroom practice, students are more likely to use effective learning strategies, seek out challenge, and see that effort goes hand in hand with success, all of which may help to override the negative impact of students' with low perceived ability (Ames & Archer, 1988)

Performance in Mathematics. One of the factors which led to the review of the national mathematics curriculum was the recent performance of UK students in mathematics in various international tests, compared to their counterparts, particularly those from East Asian countries including China. East Asian students have consistently outperformed their counterparts in Western countries in recent international studies of mathematics achievement. In the TIMSS 2007, at Grade 4 (Year 5), England's performance was significantly above the international average in all three content areas: number, geometric shapes and measures, and data display. Performance on number (and computation) was significantly lower than in the other two areas, although still above the international average. This is somewhat surprising given the mental mathematics focus of the National Numeracy Strategy (NNS) over the past decade. However, findings on achievement in number from the Leverhulme Numeracy Research Programme suggest that improvements due to the NNS have been relatively modest (Brown, Askew, Millett, and Rhodes, 2003). Taking into account both Content and Using and Applying aspects of the TIMMS, the increase in overall performance in mathematics was associated with improvements in the middle score range, but there was no significant change to the proportion of students at the highest level of performance, the advanced benchmark. Replication results from the Concepts in Secondary Mathematics and Science (CSMS) study show a similar pattern that students' understanding of some algebraic ideas has declined at the higher levels of attainment (Shayer and Ginsburg, 2009). This may support earlier discussion on the importance of achieving rapid fact retrieval (fluency and automaticity) and higher-order mathematics.

One of the unique features of the Number Masters programme© is that it is designed to be delivered in small groups, between 6-8 pupils in a group, facilitated by either class teachers or teaching assistants.

Several studies point to the success of intervention programmes delivered by TAs (e.g. Evans 2008; Savage and Carless 2008), and a research review concludes that they are likely to raise attainment if accompanied by appropriate training and guidance (Alborz et al. 2009). This programme ensures that TAs receive appropriate training and the materials themselves are so designed for ease of implementation by both teachers and teaching assistants.

Methodology and Findings

Methodology: Phase 1- October 2013

Control Group and Experimental Groups were identified. Experimental groups were schools from the Oval Cluster identified to implement the Number Masters materials in Years 1 and 2. Control groups were schools identified to continue teaching mathematics using their current curriculum, pre-2014 NC, with numbers and calculations usually taught within 3-part mathematics lessons. Majority of the participating schools were Lambeth primary school aside from one control group from Lewisham.

To determine pupils' entry behaviour prior to the experimental phase, Sandwell Early Numeracy Test was administered to a group of randomly selected Year 1 pupils from each of the control and experimental groups. SENT-R is a one-to-one assessment that enables teachers to assess children's ability with numbers. The test covers attainments from National Curriculum Level P6 to Level 2A and can be used with children aged between four and eight. It is also appropriate for use with older children whose performance in numeracy is well below average for their age group.

Descriptive statistics were carried out to establish the groups' performance in the first phase. A t-test for two samples assuming unequal variances was applied to establish whether there was a significant difference between the control group and the experimental group in their SENT-R test results. The independent t-test, also called the two sample t-test or student's t-test, is an inferential statistical test that determines whether there is a statistically significant difference between the means in two unrelated groups.

Descriptive Statistics

Experimental Group	
Mean	31.55
Standard Error	1.543242057
Median	31
Mode	39
Standard Deviation	11.95390157
Sample Variance	142.8957627
Kurtosis	1.864110151
Skewness	0.539960434
Range	66
Minimum	9
Maximum	75
Sum	1893
Count	60

A total of 79 pupils were tested from the experimental group. These were pupils from Vauxhall Primary School, Wyvil Primary School, St Andrew's Primary School, Reay Primary School. Their calculated mean score was 31.55

Control Group	
Mean	32.50632911
Standard Error	1.22479435
Median	34
Mode	34
Standard Deviation	10.88621031
Sample Variance	118.5095748
Kurtosis	-0.052638493
Skewness	-0.067733154
Range	50
Minimum	8
Maximum	58
Sum	2568
Count	79

A total of 60 pupils were tested from the control group. These pupils were from Granton Primary School, Kelvin Grove Primary School, and Christchurch Primary School.

Test of Difference: Experimental vs Control Group- Entry Behaviour

Null Hypothesis: There is no significant difference between the average means of the Experimental Group and the Control Group, when tested using SENT-R.
Alternate Hypothesis: The difference between the average means of the Experimental Group and the Control group does not equal to 0.

t-Test: Two-Sample Assuming Unequal Variances Unequal Sample Sizes	α	0.05
	Data1	*Data2*
Mean	31.55	32.50633
Variance	142.8958	118.5096
Observations	60	79
Hypothesized Mean Difference	0	
df	130	
t Stat	-0.485	
P(T<=t) one-tail	0.314	
T Critical one-tail	1.657	
P(T<=t) two-tail	0.628	
T Critical Two-tail	1.978	

To analyse the t-test results, we use:
t Stat > t critical, reject the null hypothesis
t Stat < t critical, cannot reject the null hypothesis

Therefore in this specific test, 0.48 < 1.97, the, the null hypothesis cannot be rejected.
Cannot Reject Null Hypothesis because p > 0.05 (Means are the same)

This statistical test therefore establishes that entry performance of both control and experimental groups are broadly the same when tested using the SENT-R materials and therefore the experimental phase of the research proceeded as planned.

Methodology Phase 2: Experiment Stage- October 2013 to June 2014

Number Masters© materials were delivered to the named Experimental schools in October 2013 following a short training session during the Oval Cluster joint INSET day early in September 2013. The training was delivered to both classroom teachers and teaching assistants working in Year 1 and Year 2 classes. Class teachers were advised on how to deliver the programme, and how resources are to be prepared prior to each learning week. The Extended Services Partnership manager, who co-ordinates cluster activities, ensured that the Number Masters© programme was implemented consistently across Experimental schools. This meant the programme was being delivered in the first 15-20 minutes of mathematics lessons, in lieu of the usual mental starters. Number Masters© is then followed by the main mathematics lesson for the day. Schools in the Control Group carried on teaching mathematics using the traditional mental starters-main activity-plenary structure.

Methodology Phase 3: Exit Assessment- June 2014

To determine the effectiveness of the Number Masters© materials and their impact on pupil achievement, Sandwell Early Numeracy Test B was administered to a group of Year 1 pupils from each of the control and experimental groups (the same children who took the initial assessments using Sandwell Early Numeracy Test A, research Phase 1). SENT-R is a one-to-one assessment that enables teachers to assess children's ability with numbers. The test covers attainments from National Curriculum Level P6 to Level 2A and can be used with children aged between four and eight. It is also appropriate for use with older children whose performance in numeracy is well below average for their age group.

Test of Difference: Experimental vs Control Group- Exit Assessment

Null Hypothesis: There is no difference between the average means of the Experimental Group and the Control Group, when tested using SENT-R.
Alternate Hypothesis: The difference between the average means of the Experimental Group and the Control group does not equal to 0.

t-Test: Two-Sample Assuming Unequal Variances

	Control Group	Experimental
Mean	40.47540984	51.1641791
Variance	201.1202186	164.7150611
Observations	60	79
Hypothesized Mean Difference	0	
df	121	
t Stat	4.455399812	
P(T<=t) one-tail	0.00000	
t Critical one-tail	1.657544319	
P(T<=t) two-tail	0.0000	
t Critical two-tail	1.979763763	

To analyse the t-test results, we use:
t Stat > t critical, reject the null hypothesis
t Stat < t critical, cannot reject the null hypothesis

Reject Null Hypothesis because $p < 0.05$ (Means are Different)

Therefore in this specific test, 4.45 > 1.97, the, the null hypothesis is rejected and the alternate hypothesis accepted.

This statistical test therefore establishes that exit performance of control and experimental groups are significantly different when tested using t-test, at 95% confidence level (α =0.05).

Conclusion and Recommendations

This action research confirms our initial hypothesis on the effectiveness of the Number Masters© materials in developing children's number skills and computational fluency in Key Stage 1. In addition to the significant gains made by pupils, the following observations were also noted by teachers and support staff who implemented the programme:

- There is a massive improvement in children's automatic and rapid retrieval of facts as they answered questions with ease.
- Children's engagement with mathematics is heightened as they have more opportunities to participate given that they learn in small groups.
- Mastery is facilitated not by repetition but by varied activities and by manipulation of practical equipment, while working on the same objective.
- Children show high levels of mathematical confidence as the activities are planned in small steps, aimed at pupils' feeling of and attainment of success.
- Each Number Masters© session creates a learning buzz in the classroom, with all the adults working with small groups of children who display focus, enthusiasm, and engagement.

Pupils who were taught using the **Number Masters©** materials showed enormous progress in their number skills, some achieving more than one national curriculum level.

We therefore make the following recommendations based on the findings of this research:

- Make this research available to other primary schools to provide them information about the various aspects of the programme that contribute to rapid pupils' progress in mathematics. It will also hopefully encourage other schools, or group of schools, to embark on similar researches.
- Explore the possibility of a much wider-scale research.
- Track the pupil-participants of this research and continue to make analysis of their progress to establish whether the progress they made is sustained, and therefore establish a long-term impact, if any.
- Inform other studies relating to the impact of teaching assistants in raising standards and pupil achievement in mathematics.

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