Overcoming Underachievement in Basic Number Fact Learning: Memory and Measurement are Key -- and Enthusiasm!

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Although it ended by lending support to the hypothesis that basic fact knowledge is the Achilles' heel of New Zealand mathematics education, the study started with the simple aim of finding if a particular programme could substantially help a school improve the learning of Year 5 – Year 6 students in multiplication and division basic number fact knowledge. The situation became a complex one when the level of underachievement in baseline testing was so low as to question whether the intended intervention was entirely suitable and could possibly bring students to an acceptable pre-intermediate-school standard. In the event the intervention proceeded and in large part brought remarkable gains in achievement. Since the same teachers and students were involved it was concluded that it was teaching methods that made the difference, namely a change from methods that place an early emphasis on strategy to a set of methods emphasizing memorisation with repetitive practice but allied to understanding. The study also showed the usefulness of precise measurement. AFPM (Accurate Facts per Minute) was seen to be a measure that can support a numeric and normative basis to the curriculum requirement that children 'know' their basic facts and to their need to be fluent as well as accurate in basic computation. The same measure facilitated student goal setting and monitoring of progress.

Summary and conclusions

The study aimed to see if a basic facts learning programme known as *Kiwi Maths* could improve the multiplication and division knowledge of upper-primary students. It took place by chance in a large low-decile school setting.

In baseline testing the students in all four of the Year 5/Year 6 classes which took part showed very limited basic fact knowledge and lacked fluency in recall. The great majority clearly faced serious and frustrating difficulties in their future mathematics if not outright failure. It seemed they must be among the so-called 'underachieving tail' which for some time has been a major concern in New Zealand education. A question was whether the problem was primarily with the students, or with the teachers, or lay somewhere else. The present study was able to throw some light because it *involved the same children and the same teachers but different teaching methods.*

All four of the teachers in the study had been trained in the strategy-emphasising set of basic fact teaching methods advocated under the Numeracy Development Project and widely followed in New Zealand schools. The school had enjoyed six years of Mathematics Professional Learning and Development support.

The set of methods used in intervention in this study and known to students as 'Kiwi Maths' was to a degree representative of other memorisation methods which, while involving repetitive practice and over-learning, maintained firm links with understanding. Differing markedly from the previous methods it involved short concentrated memorisation activities written and oral, required the development of accuracy within a set of facts before working on speed, required over-learning and adequate revision, enabled students to set short and long-term goals and to monitor their own progress, enabled students to daily compete against themselves and therefore have repeated experience of success, and through problem-solving activities maintain links to understanding. It was similar in important ways to remedial methods used in an ALiM study that involved daily routines of practice, informal testing and revision, teaching memorisation techniques, and ensuring that short term goals were small enough to be achievable.

The key measure used in this study was AFPM, Accurate Facts per Minute. It was chosen because it relates to two broad number-fact goals. One is the curriculum requirement that students at Level 3 will come to 'know' the multiplication and division facts. The other is that students will have procedural fluency, such as to be mentally efficient and accurate in basic computation. AFPM is a combined measure of accuracy and speed, encompassing productivity/fluency. Thus it relates to both requirements.

AFPM was also chosen because it had been shown to be easily understood by parents and students. Parents, for example, had been found to see 2 seconds per fact (30 AFPM) as the minimum standard of time-per-fact that they expected their children to reach in Level 3. Students, for their part, had been found to easily learn to set short and long-term AFPM goals for themselves and to monitor their progress to those goals.

In terms of AFPM most students were at very low levels in baseline testing. Year 5 students were at 7 AFPM in multiplication, 5 in division. Year 6 students were at 9 in multiplication. They were at 6 AFPM in division and showing only a one point gain from a whole year of schooling. Eighty-eight per cent of the Year 6 students fell below 15 AFPM (4 seconds a fact). Fifty-six per cent were below 10 AFPM and almost a third were below 5.

In a little over 6 months Year 5 students improved on average from 7 to 15 AFPM in multiplication facts. They made a 10-point gain in division from 5 to 15 in marked contrast to negligible gain under the previous methods. Year 6 students improved on average from 9 AFPM at baseline to 20 in multiplication while in division they moved from 6 to an impressive 19. Effect Size analysis showed very large improvement in each of the four classes in the study, Pasifika and Maori children alike, and for both the high-ability and regular classes.

By AFPM standards, 55% of the students in their final primary year came up to at least the 20 AFPM level that gave them a reasonable chance in their future mathematics. One in five students attained the 'good' standard of 30 AFPM and some children reached a level of excellence. In division, 64% attained at least 20 AFPM while 42% reached the 30 AFPM standard of 2 seconds a fact. One child scored at 60 AFPM, one second a fact.

The intervention did not succeed with all children. In a future similar research study, one would broadly assess participants in advance in order to explain why. Twelve per cent of the Year 6 students remained seriously underachieving in multiplication and 14% per cent in division. These students face intermediate school very poorly prepared and need remedial follow up.

Major factors underlying this underachievement are regularly claimed to relate on the one hand to the quality of teachers and on the other to socio-economic factors relating to children. The present study shows that, at least in some important areas of education, teaching methods may be a third factor of critical importance. In this study the same teachers working with the same children achieved highly successful results with different methods.

Alarmingly, neither the school leadership, nor ERO, nor the Board of Trustees, nor the parents were originally aware of the basic facts knowledge levels of students and so did not take significant remedial action. This finding highlights *the importance of testing basic fact knowledge* and, then, of taking action in respect of weakness found.

Lack of knowledge of achievement levels applies also at Ministry level. NEMP studies provided invaluable information at year 4 and year 5 from the NEMP studies, but beyond this the true state of basic number fact knowledge and competence in our schools – most alarmingly in basic division - is largely unknown. Surprisingly, for this small but extremely important part of mathematics education, the Ministry does not require schools to collect data and report either to their boards or to ERO, though some schools voluntarily do so in one way or another. It is recommended that it do so, or recommend to Boards that they specifically demand this information for the edification of parents.

AFPM, as a concept and as a measure, has many benefits. It deserves to be embraced by the Ministry and widely used in schools.

- It is numeric. The curricular requirement that children will 'know' their basic facts is quite vague. AFPM enables it to be defined numerically and in relation to productivity and fluency.
- In test form it is useful for start-of-year baseline testing, for student and class goal-setting, for monitoring progress through the year and for end-of-year analysis.
- Built into exercises it can be motivating for students. It is built into *Kiwi Maths* activities and with Intellectual property rights waived - can easily be built into others.
- It facilitates data collection and gathering of information. The Ministry may develop norms from such data and set standards – and certainly use it in its own research.

This study clearly indicates that the current Ministry-approved basic fact teaching methods are failing many children and supports conclusions that one can make from NEMP data that our knowledge achievement standards are low, and may indeed be our 'Achilles' heel in mathematics education.

Underachievement can be reversed as ALiM interventions and the present study show. But in many schools the teaching methods they used, or other like them, need to be part and parcel of everyday school maths and not left to become remedial interventions. In the end the actual choice of methods should be determined by results, by measurement. How well do they work? Test and find out! *Measurement is key.* And if methods and procedures aren't working, change them.

Underachieving students are inherent achievers, as this study has shown. It needs only government support, at very small cost, to reverse current deficit. In a matter of months trials in a few schools could confirm if the present study's findings are valid - and at the same time *check on the extent to which much-improved basic fact knowledge impacts on mathematics progress in general and if it may actually enhance rather than impair the development of part-whole and strategic thinking.*

It would honour the teachers and students who took part in the present study if such trials were to happen and happen soon, for in the meantime it is believed that thousands of children endure advocated teaching methods that lead them steadily towards failure in mathematics.

It would honour also scientists who with their pigeon navigating studies help us understand that true basic fact learning occurs when children, as they work on maths problems, are able to navigate freely keenly and confidently within basic fact databases developed in *memory.*

In the future it may honour the Minister and Ministry staff who became *enthusiastic* about the importance of such learning and effectively helped to bring it about.

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