Longitudinal Progress of 6-year-old Students Who Participated in an 'Extending Mathematical Understanding' Mathematics Intervention Program

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The longitudinal progress of 42 Grade 1 students who participated in a 10-20 week Extending Mathematical Understanding (EMU) intervention program was examined to evaluate the effectiveness of the program for enhancing and accelerating mathematics learning. Overall the students made accelerated progress during Grade 1 and their learning was maintained after the six-week summer break and also when they were assessed 12 months later. However, the rate of progress for many students was less during Grade 2 when they participated only in regular classroom lessons.

Governments and school communities recognise the value of identifying, early in schooling, the students who are not thriving mathematically and providing them with more intensive instruction. Indeed, providing intervention programs for vulnerable students is a key factor in a whole school approach for improving learning outcomes (Fullan, Hill & Crevola, 2006; Gervasoni, Parish, Upton, Hadden, Turkenburg, Bevan, Livesey, Thompson, Croswell & Southwell, 2010). However, many primary schools do not have teachers with specialist knowledge about diagnosing mathematics difficulties and designing instruction to accelerate students' learning. The *Extending Mathematical Understanding* (EMU) Specialist Teacher Course and the EMU Intervention Program (Gervasoni & Lindenskov, 2011) were designed to achieve this objective. This paper explores the longitudinal progress of 42 Grade 1 students (6-year-olds) who participated in an EMU Program in 2010 as part of the *Bridging the Numeracy Gap Project* (Gervasoni, Parish, Hadden, Turkenburg, Bevan, Livesey, & Croswell, 2011). The question framing the research is: What is the progress over 24 months of Grade1 students who participated in a 10-20 week EMU Intervention Program?

The Bridging the Numeracy Gap Project

The *Bridging the Numeracy Gap* Project (Gervasoni et al., 2011) was a collaboration between 44 s chools, four Catholic Education Offices (CEOs) in Australia (Ballarat, Sandhurst, Sale and Western Australia) and Australian Catholic University. It aimed to improve mathematics learning for students in the early years of schooling. Key approaches used were: classroom teachers using the one-to-one *Early Numeracy Interview* (Clarke, Sullivan, & McDonough, 2002; Gervasoni, Turkenburg, & Hadden, 2007) to assess all students at the beginning of the year and then design appropriate instruction for all students; and using the *Extending Mathematical Understanding* Intervention Program (Gervasoni, 2004) to provide intensive specialised instruction for students identified through the assessment as mathematically vulnerable.

The Early Numeracy Interview (Department of Education Employment and Training, 2001), developed as part of the Early Numeracy Research Project (ENRP, Clarke et al.,

In V. Steinle, L. Ball & C. Bardini (Eds.), Mathematics education: Yesterday, today and tomorrow (Proceedings of the 36th annual conference of the Mathematics Education Research Group of Australasia). Melbourne, VIC: MERGA.

2002), is a cl inical interview with an associated research-based framework of growth points that describe key stages in the learning of mathematics in nine mathematics domains. This interview and the growth points were used to obtain the data examined in this paper so it is important that both are well understood. The principles underlying the construction of the growth points were to: describe the development of mathematical knowledge and understanding in the first three years of school in a form and language that was useful for teachers; reflect the findings of relevant international and local research in mathematics (e.g., Steffe, von Glasersfeld, Richards, & Cobb, 1983; Fuson, 1992; Wright, Martland, & Stafford, 2000; Gould, 2000); reflect the structure of mathematics; describe the mathematical knowledge of individuals and groups; and identify students who may be mathematically vulnerable.

The processes for validating the growth points, the interview items and the comparative achievement of students are described in full in Clarke et al. (2002). To illustrate the nature of the growth points, the Multiplication and Division growth points are shown in Figure 1. These emphasise the strategies students use to solve multiplicative tasks.

1. Counting group items as ones – in a multiple group situation the student refers only to single items
2. Modelling multiplication and division (when all objects perceived) to solve problems.
3. Partial modelling multiplication and division (some objects perceived) – solves problems where objects are not all modelled or perceived.
4. Abstracting multiplication and division (no objects perceived)) – solves problems where no objects are modelled or perceived.
5. Basic, derived and intuitive strategies for multiplication) – using strategies such as commutativity and building up from known facts.
6. Basic, derived and intuitive strategies for division.
7. Extending and applying multiplication and division in complex/practical situations.

Figure 1. Growth points for the Multiplication and Division Strategies domain.

Each growth point represents substantial expansion in knowledge along a path to mathematical understanding (Clarke, 2001). Growth points enable teachers to identify students' zones of proximal development so that instruction may be precise, and to identify students who may be mathematically vulnerable in any domain. The whole number tasks in the interview (in the domains of Counting, Place Value, Addition and Subtraction Strategies, and Multiplication and Division Strategies) take about 15-25 minutes per student and are administered by the classroom teacher. There are about 40 tasks in total, and given success with a task, the teacher continues with the next tasks in a domain (e.g., Place Value) for as long as the child is successful, and according to the interview script.

The Extending Mathematical Understanding (EMU) Intervention Program

The intervention program investigated in this study was the Extending Mathematical Understanding Intervention Program (Gervasoni, 2004). This is a series of lessons expressly designed by a specialist teacher for the purpose of accelerating learning for the most vulnerable students in a class. Students are prioritised for participation on the basis of their ENI assessment profiles and extra information from classroom teachers. Groups of three students participate in 30-minutes lessons, 5 days per week for a total of 50-100 lessons, depending on student progress. Each lesson centres on whole number learning with specific emphases on quantity or numerosity (including place value and counting), investigations involving the four operations with an emphasis on the development of reasoning strategies, reflection on learning, and a home task. EMU specialist teachers have completed an additional course (at Masters level) that includes 36 hours of course work, a minimum of 25 hours of field-based learning, and a program of professional reading.

Identifying Eligible Students for an EMU Intervention Program

All students in participating schools were assessed by their classroom teachers at the beginning of 2010 and 2011 with the *Early Numeracy Interview*. This assessment was used by teachers to get to know their students mathematically so that they might refine the curriculum for class groups and individual students. The assessment was also used to identify any students who were mathematically vulnerable in any domain and who may benefit from an intervention program. The ENRP research-based set of growth points were used for this purpose (Gervasoni, 2004). Students identified as mathematically vulnerable in any domain were then prioritised for participation in the EMU Program.

The record sheets completed by teachers during the interviews were analysed by independent coders to determine the growth points students reached in each domain. These were entered into an SPSS data base for analysis along with information about the background of each student, including whether or not they had participated in an EMU Program, and if so, the total number of lessons. These data were also analysed to explore the progress of the students 12 months after they completed an EMU Intervention program.

In 2010, 136 of 699 (19%) Grade 1 students from 26 schools across Australia were prioritised for some additional mathematics support or participation in an EMU Intervention Program. There were 55 boys (40%) and 81 girls. Of these 136 students, only 42 participated in an EMU Program for 10-20 weeks (between 50 and 100 thirty-minute lessons). Due to limited resources few schools were able to provide intervention programs for all eligible students. Some schools were able to offer additional support for vulnerable students but not with the regularity required for the EMU Intervention Program.

Longitudinal Progress of Students Participating in an EMU Program

Forty-two students had the chance to participate in an EMU Program in 2010. They were the most mathematically vulnerable students in their class based on their ENI assessment and growth point profiles (Gervasoni, 2004). Analysis of these students' initial growth points suggests that they were a diverse group. Some were vulnerable in only one domain (21%), some in two (31%) or three domains (33%), but only four students (10%) were vulnerable in all four domains (Gervasoni et al., 2012). Clearly there is no one pattern to describe children who are mathematically vulnerable. This highlights the complexity of teaching and the need for teachers to be expert at assessing students` knowledge and in designing customised instruction that enables all students to learn.

In order to show the progress of students who participated in an EMU Program in 2010, their growth point distributions in 2010, 2011 and 2012 for each domain were calculated and compared with all students in their cohort. As an illustrative example, Figure 2 shows the growth point distributions for Multiplication and Division. Note that due to the larger project ending in 2011, data for all the 2012 Grade 3 cohort was unavailable, so 2011 Grade 3 data is used as indicative of the distribution that might be expected of the 2012 cohort. The asterix highlights this use of 2011 Grade 3 da ta in Figures 2-5.

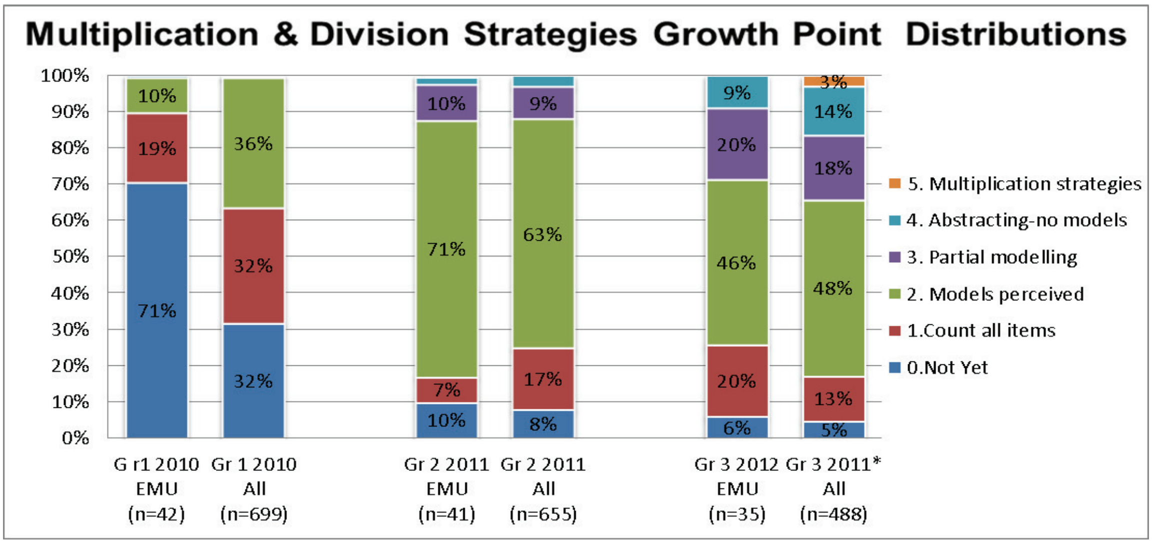

Figure 2. Progressive (2010-2012) Multiplication & Division growth point distributions (beginning of the year) for the 2010 EMU group and comparison data for all Grade 1, Grade 2 and Grade 3 students.

Figure 2 highlights that for the 2010 EMU group substantial growth occurred by 2011 for most students. Further, it is striking how similar the growth point distributions are in 2011 for both the EMU group and the *all students* group. This finding was also apparent for the other three whole number domains (see Figures 3-5). These data suggest that one effect of the EMU Program was an acceleration of whole number learning to the point that the EMU group's growth point distribution mirrored that of *all students* one year later. Nevertheless, some EMU students remained on the lowest growth points despite the fact that others had progressed two or three growth points.

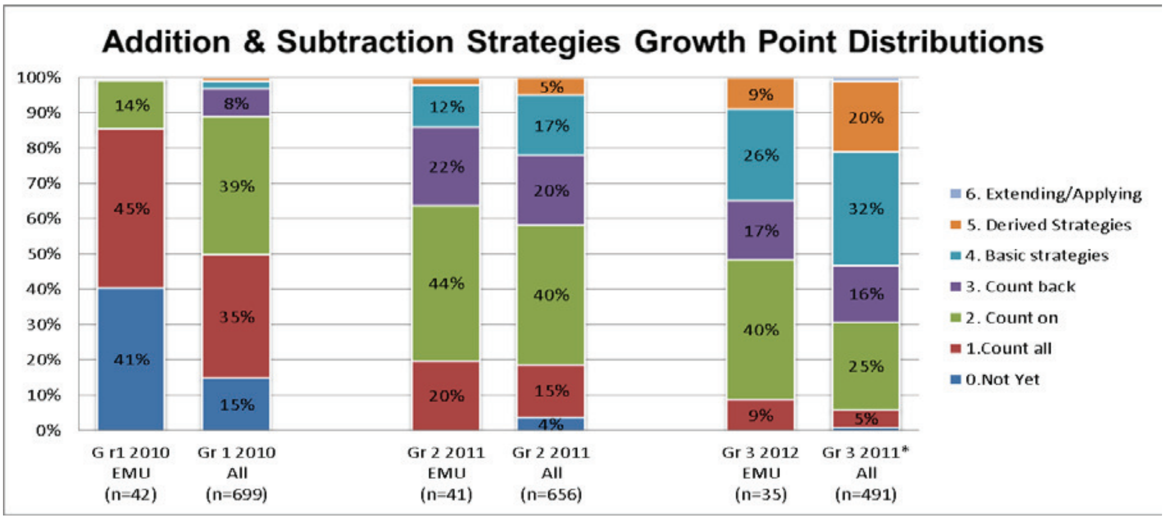

Figure 3. Progressive (2010-2012) Addition & Subtraction growth point distributions (beginning of the year) for the 2010 EMU group and comparison data (2010-2011) for all Grade 1, Grade 2 and Grade 3 students.

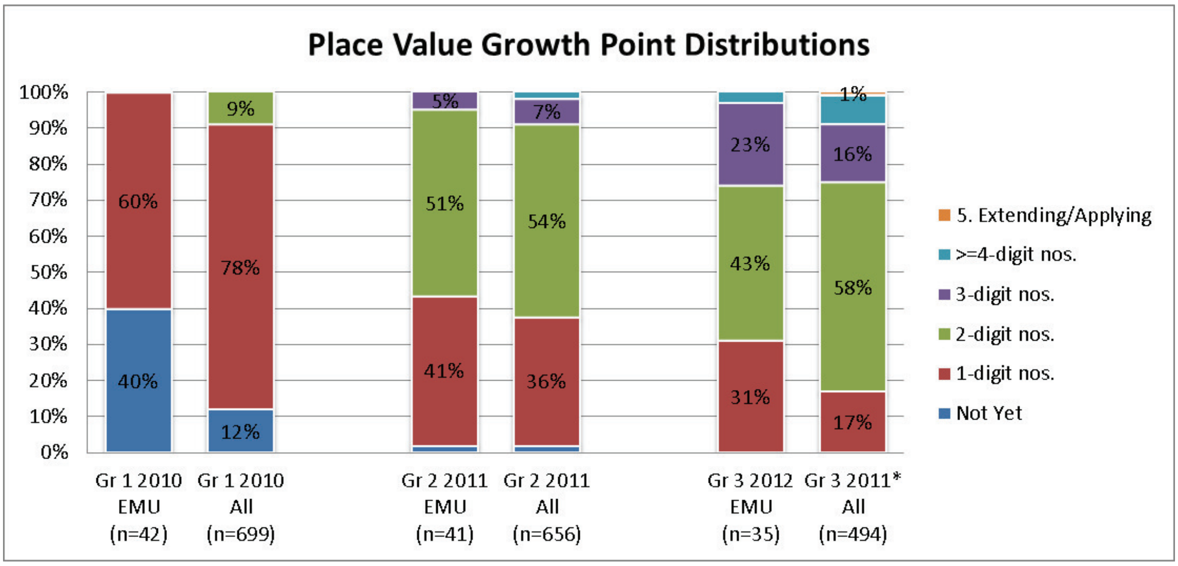

Figure 4. Progressive (2010-2012) Place Value growth point distributions (beginning of the year) for the 2010 EMU group and comparison data (2010-2011) for all Grade 1, Grade 2 and Grade 3 students.

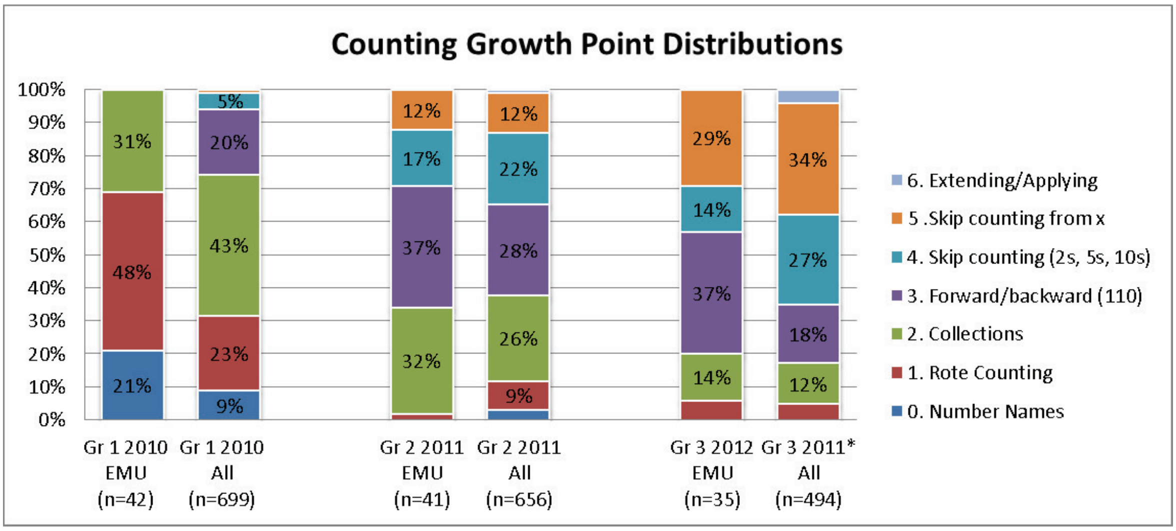

Figure 5. Progressive (2010-2012) counting growth point distributions (beginning of the year) for the 2010 EMU group and comparison data (2010-2011) for all Grade 1, Grade 2 and Grade 3 students.

Although it is evident that overall most students participating in the EMU intervention program made good progress in each domain by the beginning of Grade 2, it is important to consider whether their progress continued at the same rate when they no longer had the opportunity afforded by an intervention program. A comparison of the Grade 2 and Grade 3 Multiplication and Division growth point distribution (Figure 2) for the EMU group suggest that little or no progress occurred for many students across their Grade 2 year. Moreover this is apparent for both the EMU and comparison groups. It is important to note that a growth point represents a significant milestone in a student's development that may take 12 months to achieve, as opposed to smaller steps in learning that are noticeable every day. However, the situation is quite different for those students in the upper quartile of the distribution at the beginning of Grade 2. Against the trend, these students progressed one additional growth point from 2011 to 2012 in the Multiplication and Division Strategies domain, and similar growth is apparent also for students in the upper quartile of the distribution in the other domains (Figures 3-5).

Another interesting comparison to note is the progress of students from Grade 2 to Grade 3 in the Addition and Subtraction domain (Figure 3). In general, students in the upper 50% of the Grade 2 distribution progressed one growth point by Grade 3, but the learning for most students in the bottom half of the Grade 2 distribution appears to have stagnated. Thus it seems that if students reach Growth Point 3 (count-up-to strategy) by the beginning of Grade 2, then they are likely to make progress by Grade 3. Otherwise their progress seems more likely to stagnate, with students typically continuing to use the *count-on* strategy to solve addition calculations. This appears true also for the students in the comparison group.

In Place Value, comparisons between the growth point distributions for Grade 2 and Grade 3 for both the EMU group and *all students* suggest that if they begin Grade 2 on Growth Point 1 or 2 (one and two-digit numbers respectively), then they are quite likely to remain on these growth points one year later. This suggests that Grade 2 classroom instruction was not sufficient for these students' learning needs in Place Value.

Inspection of EMU students' progress in the Counting domain suggests that this was accelerated across Grade 1 for all students, but that progress for some stagnated across the Grade 2 year, particularly if they had reached Growth Point 2 (count at least 20 objects) or Growth Point 3 (count by ones past 109 and back from 24). In contrast, the EMU students who had reached Growth Point 2 at the beginning of Grade 1 all progressed to Growth Point 3 one year later. This suggests that that the classroom Counting curriculum and instruction provided for Grade 2 students may not have been sufficient for students who are on Growth Point 2 or Growth Point 3 at the beginning of the year.

Discussion and Conclusion

Analysis of the 2010-2012 whole number knowledge of students participating in the *Bridging the Numeracy Gap* Project and 42 students who participated in an EMU Intervention Program in 2010 highlights the remarkable range in their growth point distributions and progress, and thus the complexity of classroom teaching. The data presented in Figures 2-5 also identifies that there are some students on much lower growth points than their peers. For example, in contrast to the majority and despite 12 months at school, some Grade 1 students were unable to count a collection of 20 items, or count all objects to solve addition and subtraction problems, or multiplication and division problems. These students may have difficulty accessing and benefiting from the Grade 1 curriculum that typically assumes this knowledge.

Forty-two Grade 1 students on the lowest growth points had the opportunity to participate in an EMU Intervention Program designed to accelerate their mathematical learning and assist them to benefit from the classroom mathematics program. Analysis of their whole number knowledge showed that they are a diverse group but that very few were vulnerable in all four whole number domains (Gervasoni et al., 2012). Moreover, there was no one pattern to describe these students' whole number knowledge or learning needs. The implication of this finding is that specialist teachers need to be expert at assessing each student's current mathematical knowledge, and in designing highly responsive instruction based on this assessment. It is also important to note that very few members of the EMU group had other learning difficulties. Few participated in the *Reading Recovery* intervention program (Clay 1993), had language backgrounds other than English or were assessed with severe language difficulties (Gervasoni et al., 2012). Often it is assumed that lower achievers in mathematics have a range of factors affecting their opportunity to thrive in mathematics learning, but this was not typical of most students in this group.

An important focus for this paper was reporting on the progress of students who participated in an EMU Program in Grade 1 across their following Grade 2 year. The students were assessed by their classroom teachers at the beginning of 2010, 2011 and 2012 and this provided a measure of their whole number learning across this period. Overall, the forty-two EMU students made very good progress across Grade 1 and achieved significant growth by the beginning of 2011 that was maintained after the extended summer holidays. Findings from the *ENRP* (Clarke et al., 2002) suggest that mean growth for 6 and 7-year-old students across one year was about one growth point in each domain, and somewhat less in Place Value. By 2011, the students participating in the EMU Program in 2010 progressed between 5 and 11 growth points in the four Whole Number domains overall. There were some students who did not progress in particular domains, but most improved two growth points per domain, although this was rare in Place Value. The acceleration of learning for the EMU group is obvious when comparing the growth point distributions of the EMU students when they reached Grade 2 with all Grade 2 students. Indeed, by Grade 2 (2011) and again in Grade 3 (2012), the growth point distributions of both groups were very similar compared with the differences observed in 2010. However an important issue apparent in the EMU group Grade 2 and Grade 3 Growth Point distributions is that learning for some students seemed to stagnate; generally it was students in the top quartile that progressed. This finding suggests that classroom instruction for Grade 2 students may not be meeting the mathematics learning needs of all students. The analyses also suggest that participation in an EMU Program in Grade 1 did not accelerate learning for all students in all domains. Further, a proportion of the students were still mathematically vulnerable in the following two years. In contrast, a quarter of the EMU group reached the highest growth points in the 2011 and 2012 distributions for all students.

The EMU Program was successful in enabling most Grade 1 students to progress their whole number learning beyond that anticipated in a typical year. This was true even for the students who began on the lowest growth points. Profitable areas for further research and development are: (a) seeking insight about why some students make less progress during an intervention program than others, and (b) designing classroom instruction for Grade 2 students that will maximise learning for all. It is likely that some students may benefit from more specialised mathematics instruction beyond Grade 1, and also that classroom instruction in Grade 2 may need to be more responsive to students' individual learning needs.

Acknowledgements

The research reported in this paper was funded by the Australian Government as part of the *Bridging the Numeracy Gap in Low SES and Indigenous Communities* Project. The authors acknowledge gratefully the contribution of all participating teachers, parents, students and school communities.

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