Insights About the Progress of Grade 1 Children Who Are Mathematically Vulnerable and Participate in a Mathematics Intervention Program

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This paper reports on the longitudinal results over 12 months of 342 Grade 1 children from 57 schools in Sydney, Australia, who participated in the *Extending Mathematical Understanding* (EMU) Intervention Program. Their vulnerability in four whole number domains is described, and the extent to which this changed after 12 months. Overall the EMU students made accelerated progress when compared with all Grade 1 students (N = 3277) and the number of domains for which they were vulnerable decreased when assessed 12 months later. However, 75% of the children who received this supplementary support remained vulnerable in at least one number domain the following year.

Introduction

The issue of how to assist all children to thrive when learning mathematics continues to be important for school communities and governments. However, Cobb, Jackson, Henrick, and Smith (2018) argued that system approaches for improving mathematics learning for students typically underestimate the need to provide high-quality supplementary supports for currently struggling students. They found that mathematics teachers "need to develop a relatively sophisticated image and vision of what high-quality teaching looks like, and to realise that all their students can engage in rigorous mathematical activity if they are given appropriate support" (p. 9). Similarly, Gervasoni and Lindenskov (2011) argued that there is a group of students who struggle in mathematics due to their "explicit or implicit exclusion from the type of mathematics learning and teaching environment required to maximise their potential and enable them to thrive mathematically" (p. 308).

Supplementary Supports for Students Who Struggle with Mathematics

The specific features of supplementary supports that aim to assist children who are vulnerable when learning mathematics vary widely. Recently, there have been attempts to provide advice about the approaches that seem most promising. For example, the National Joint Committee on Learning Disabilities (2016) outlined five critical areas of attention to support currently struggling students to achieve high-quality education standards. These were: (1) high-quality, collaborative, professional development; (2) appropriate curriculum and instructional design; (3) appropriate assessments that reveal students' strengths, needs, and achievement levels; (4) a comprehensive understanding of the whole child; and (5) a comprehensive and effective transition planning" (Gartland, & Strosnider, 2017, p. 154). This advice suggests the need for teachers to have a vision of high-quality teaching, but does not elaborate what this might be in the context of mathematics.

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Jitendra (2013) has identified five effective classroom teaching practices to support students who are most at risk for difficulties in learning mathematics. These practices are: (1) maintaining the cognitive demand of the lesson; (2) promoting the development of conceptual understanding; (3) providing opportunities for students to make conjectures about mathematical ideas; (4) attending to student thinking and mathematical reasoning by having students explain their responses or particular strategies or representations; and (5) using students' statements about mathematics to build class discussion (p. 6). However, a review by McKenna, Shin, and Ciullo (2015) of eleven studies focussing on instruction for students with learning difficulties, noted that, despite recommendations emphasising the importance of developing conceptual understanding, mathematical reasoning, problem solving, cognitive strategy instruction and visual representations, these approaches were seldom noted across the published research.

Mathematics intervention programs that offer supplementary supports to accelerate or boost children's mathematics learning are structured in different ways. Some have a multi-level approach, with each level of intervention increasing the intensity of support. For example, Response to Intervention (RTI) (Berkeley, Bender, Peaster, & Saunders, 2009; Gersten, et al., 2009) is a 3-tiered model that aims to first address the needs of all children in their regular classroom through providing high quality mathematics teaching. Second tier instruction in small groups is provided for students who have not made meaningful progress in the regular classroom. This support aims to boosts the students' knowledge and skills so that they can be successful in the classroom once the more intense support is removed. Tier 3 support includes highly intensive individualised instruction. Another feature of the RTI model is initial screening of all students, progress monitoring, and evidence-based teaching (Regan, Berkeley, Hughes, & Brady, 2015).

In Australia, supplementary supports in mathematics for six-year-old children have included *Maths Recovery* (Wright, 2003) and *Extending Mathematical Understanding (EMU)* (Gervasoni, 2004; 2015). Both programs focus strongly on children developing deep conceptual understanding and confidence through opportunities to work intensively with a specialist mathematics teacher.

The Extending Mathematical Understanding (EMU) Intervention Program

The research-based supplementary support used by the 57 schools participating in the research reported in this paper was *Extending Mathematical Understanding* (Gervasoni, 2004; 2015). This approach is used widely in Victoria, New South Wales (NSW) and Western Australia. It aims to support currently struggling students through providing 3 levels of supplementary supports provided by a specialist teacher. The most mathematically vulnerable Grade 1 children participate in an EMU intervention program that aims to boost the children's learning and confidence. The teaching approach is based on a social constructivist (Cobb, Yackel, & Wood, 1992) view of learning and engages groups of three children in learning opportunities that require high-cognitive demand across each lesson. Children are prioritised for participation in the EMU program on the basis of their assessment profiles and priority scores derived from the Mathematics Assessment Interview (Gervasoni, et al., 2011) and additional information provided by their classroom teachers. The EMU program involves 30-minutes lessons, 5 days per week for a total of 10-20 weeks (i.e. 50-100 lessons), depending on children's progress. The lessons are designed and customised for each student because of the diverse range of mathematics knowledge noted amongst those who are mathematically vulnerable (Gervasoni, 2015; Gervasoni & Sullivan, 2007). Each lesson focuses on whole number learning with specific emphases on quantity or numerosity (including place value and counting knowledge), mathematical investigations and open tasks involving the four operations with an emphasis on the development of

heuristic arithmetic and reasoning strategies, reflection on learning, and a daily home task to engage families in the children's learning. Specialist teachers are encouraged to be responsive to what they learn about each student. Children use concrete models to assist with the construction of new knowledge and are prompted to simulate, imagine and describe strategies involving these models, to explain their thinking and strategies, and to develop confidence. The EMU specialist teachers complete a 36-hour course (at Masters level) that focuses on assessing children's current knowledge, mathematical pedagogical content knowledge, and instructional design to accelerate mathematics learning. Teachers also completed at least 25 hours of field-based learning, and a program of professional reading in order to be accredited to teach the EMU program.

The aim of the research reported in this paper was to gain insight about Grade 1 and Grade 2 children who are currently struggling with number learning, and the impact of the EMU intervention program for providing supplementary support for Grade 1 children. Specifically, the following questions are explored:

1. What is the prevalence of vulnerability for Grade 1 children in each whole number domain in February 2018 and 12 months later?
2. What is the longitudinal impact of the EMU intervention program for 342 Grade 1 children who were the most mathematically vulnerable in their schools in 2018?

Method

In order to gain insight about the current whole number knowledge of Grade 1 students who were mathematically vulnerable, and the longitudinal progress of children who participated in the EMU program across 12 months, the mathematics assessment data were examined for 3277 Grade 1 students from 57 schools in a region of Sydney, NSW. Classroom teachers in these schools assessed all K-6 students in February each year using the task-based *Mathematics Assessment Interview* (MAI) (Gervasoni et al., 2011), and analysed the data to determine each child's growth points in Counting, Place Value, Addition and Subtraction Strategies, and Multiplication and Division Strategies. This process is described in full in Clarke et al. (2002). The growth points describe the progression of children's learning. Based on the assessment data, the teachers identified any children who were currently mathematically vulnerable, using the guidelines identified during the *Early Numeracy Research Project* (ENRP) (Clarke et al., 2002). All data were collated by the regional office for analysis by the research team, according to the ethical guidelines.

To illustrate how the research-based set of growth points (Clarke et al., 2002) were used to identify any students who were currently struggling, each student's current growth points were compared to a set of benchmarks known as the *On the Way* growth points (see Figure 1). These growth points describe the mathematical understanding that assumes children will be able to fully engage with typical learning experiences in their classrooms, but otherwise may struggle to engage and learn. For example, Grade 1 students on Growth Point 0 (GP0) in Place Value were identified as vulnerable because it was anticipated that they would struggle to fully participate in classroom mathematics activities that assume that children can at least understand and interpret 1-digit numbers (Growth Point 1). Similarly, Grade 2 students who had not reached Growth Point 2 (understanding and interpreting 2-digit numbers) were identified as mathematically vulnerable in Place Value, according to the process outlined in the EMU Program Guidelines (Gervasoni, 2004; 2015). The guidelines were established during the *Early Numeracy Research Project* (Clarke et al., 2002) and extended during the *Bridging the Numeracy Gap Project* (Gervasoni et al., 2011) through analysing 3 sets of data: growth point distributions for large cohorts of children in the

projects; mathematics curriculum statements; and teachers' recommendations (Clarke et al., 2002, Gervasoni, 2004; Gervasoni, 2015).

Students' overall growth point profiles (e.g., 2101 – comprising each of the growth points Counting, Place Value, Addition and Subtraction, and Multiplication and Division), and any vulnerability in these domains were used to prioritise children (Priority 1 to Priority 4) for supplementary teaching, including the EMU intervention program.

Number Domains	February–June *On the Way* Growth Points for Each Grade Level								
	F	**1**	**2**	**3**	**4**	**5**	**6**	7	**8**
Counting	[1]	2	3	4	5	5	5	6	6
Place Value	[1]	1	2	3	3	4	4	5	6
Add & Sub	-	1	2	3	4	5	5	5	6
Mult & Div	-	1	2	3	3	4	5	5	6

Figure 1. The On the Way growth points for Years 1-8 students

Of the Grade 1 children who were identified as mathematically vulnerable in any domain in 2018, 342 participated in an EMU intervention program for up to 20 weeks. These were the most vulnerable students in each of the 57 schools. For any remaining children on the priority list, mathematics individual learning plans were co-developed by the specialist teacher and classroom teachers. Some children also received in-classroom support from the EMU specialist teacher.

Results

To provide insight about the prevalence of mathematical vulnerability for 3277 Grade 1 children in February 2018 and 12 months later, the percentage of children who were vulnerable in each domain were calculated according to whether they reached the *On the Way* minimum growth point profile (see Figure 1) of *2111* in Grade 1 (count 20 objects, interpreting 1-digit numbers, count-all in addition and subtraction, and count-all in multiplication and division), and *3222* in Grade 2 (count forwards and back beyond 109, interpret 2-digit numbers, count on in addition and subtraction, and use the multiplicative structure when models are present). The results are shown in Table 1.

Table 1
Percentage of the Grade 1 Cohort Who Were Vulnerable in Each Domain in February 2018 or in Grade 2 February 2019

Assessment Year (Grade)	No. of children	Counting	Place Value	Addition & Subtraction	Multiplication & Division
Feb 2018 (Grade 1)	3277	27%	10%	14%	24%
Feb 2019 (Grade 2)	3058	35%	32%	19%	21%

The data in Table 1 shows that a higher proportion of children were vulnerable in Grade 2 for Counting, Place Value, and Addition and Subtraction Strategies than at the beginning of the previous year in Grade 1. This proportion was most pronounced for Place Value in Grade 2 when the On The Way growth point is for children is to read, write, order and interpret 2-digit numbers (Growth Point 2) as opposed to read, write, order and interpret

1-digit numbers in Grade 1. For Multiplication and Division Strategies, the percentage of vulnerable students decreased when children reached Grade 2. Overall the trend was for more children to be vulnerable in Grade 2 than in Grade 1.

Grade 1 Children Prioritised for Supplementary Support in 2018

Following analysis of the MAI data for all Grade 1 children in February 2018, 1471 children (45%) were identified as vulnerable in at least one whole number domain. The intervention specialist teacher in each school analysed the data to prioritise children for participation in an EMU intervention program, according to the number and combination of domains for which they were vulnerable. In 2018, 342 children (EMU students) from 57 schools participated in the Grade 1 EMU intervention program and were also present for the MAI in Grade 2 so that their growth could be measured. These represent 23% of the 1471 Grade 1 children who were vulnerable in at least one number domain, and 10% of the Grade 1 cohort overall (N=3277). This finding demonstrates that schools had the capacity to provide EMU programs for about one-quarter of students who were struggling.

Although the EMU program guidelines stipulate that children be provided with EMU intervention lessons 5 days per week to achieve the intensity required for an acceleration effect, the mean number of days children actually participated in EMU lessons was 3.8 days per week. Teachers reported that the major reason for missing lessons was a special school event or staffing interruptions, not student absenteeism.

Domains and Combinations of Domains for EMU Intervention Participants

To consider the mathematical domains in which EMU participants were struggling to progress, the percentage of EMU students who were vulnerable in each domain and combinations of domains were calculated (see Table 2) for 2018 and 12 months later in 2019. In 2019, mathematical vulnerability was determined by a child not yet reaching the Grade 2 On the Way growth point profiles which were each one growth point higher.

For the 342 EMU students at the beginning of Grade 1 and prior to commencing the EMU program, the data in Table 2 highlight the variability of domains and combinations of domains for which these EMU participants were vulnerable. The majority were vulnerable in one or two domains. Counting was the most common single domain for which children were vulnerable (not yet able to count at least 20 objects and knowing the new total when one object is removed), and Counting plus Multiplication and Division was the most common combination of domains. In Multiplication and Division this meant that the children were not yet able to work out the total for two teddies sitting in each of four cars, or 12 teddies divided equally between four picnic mats. The data show that only 15% of EMU participants were vulnerable in all 4 domains. This finding represents less than 0.5% of children in the whole Grade 1 cohort and suggests that it is rare for children to be vulnerable in all number domains.

Table 2 also presents the domains and combinations of domains for which these EMU students were vulnerable 12 months later when assessed at the beginning of their Grade 2 year. Against the trend shown in Table 1, fewer EMU students were vulnerable in each domain than when in Grade 1, and this decrease was greatest for both the Counting and Multiplication and Division domains. Further, 21% of the children were not vulnerable in any domains. Compared to the Grade 2 On the Way growth points, the mean number of domains for which children were vulnerable at the beginning of Grade 2 was 1.65 domains as opposed to 2.23 domains when they were in Grade 1. A paired t-test was performed and found there was a statistically significant decrease from 2018 (M = 2.23, SD = 1.09), to 2019 (M = 1.65, SD = 1.31), t (29) = 7.93, $p < 0.001$ (two-tailed). The mean decrease was 0.58

with a 95% confidence interval ranging from 0.44 to 0.72. The eta squared statistic (0.16) indicated a large effect size.

Table 2

Frequency and Percentage of EMU Students Who Were Vulnerable in Each Domain and Combination of Domains in Grade 1 (Feb 2018) and 12 Months Later in Grade 2 (Feb 2019)

Total no. Domains Vulnerable	Count-ing	Place Value	Add & Sub	Mult & Div	Pre-EMU Feb 2018 Total Vulnerable (GP Profile < 2111)	Pre-EMU Feb 2018 % Vulnerable (GP Profile < 2111)	Post-EMU Feb 2019 Total Vulnerable (GP Profile <3222)	Post-EMU Feb 2019 % Vulnerable (GP Profile <3222)
0					12	4%	86	25%
1	✓				61	25%	37	23%
		✓			0		15	
			✓		10		11	
				✓	14		18	
2	✓	✓			20	32%	33	23%
	✓		✓		33		16	
	✓			✓	53		6	
		✓	✓		0		8	
		✓		✓	2		6	
			✓	✓	3		8	
3	✓	✓	✓		18	24%	34	19%
	✓		✓	✓	38		7	
	✓	✓		✓	26		18	
		✓	✓	✓	0		5	
4	✓	✓	✓	✓	52	15%	34	10%
Total					342		342	
Total 2018 Total 2019	301 185	169 153	154 123	188 102				
Mean no. domains vulnerable					2.23		1.65	

Table 3 shows the variation in progress across 12 months for nine EMU intervention students from one school. These data provide an illustrative example of the variability of growth amongst the children who worked with the same EMU specialist teacher. All students began the intervention in March and finished between June and September 2018.

Five of the nine children increased between 7-11 growth points across 12 months. This is twice the average *one growth point per year per domain* noted in the ENRP findings (Clarke et al., 2002). Two of these five also received *Reading Recovery* during Grade 1, and three spoke English as an additional language. The growth of the remaining 4 children, even with an intensive EMU intervention program, was between 1-3 growth points in total.

Table 3
Profiles and the Number of Domains Vulnerable of 9 EMU Students in 2018 and 2019 (Pre and Post EMU), the Increase in Growth Points, and the Number of EMU Lessons Attended.

Name ID	MAI GP Profile 2018	MAI GP Profile 2019	Total GP Increase 2018-19	No. vulnerable domains Feb 2018	No. vulnerable domains Feb 2019	Total No. of EMU lessons	Other Support: RR, LD EAL*
SE	1101	5243	11	2	0	81	RR, EAL
JT	1120	5242	9	2	0	86	EAL
VT	1121	4244	9	1	0	50	-
CM	1110	4241	8	2	1	51	-
HV	1111	3242	7	1	0	85	RR
AA	1110	2202	3	2	2	88	EAL
XM	1122	2222	2	1	1	90	-
SR	0121	3201	2	1	2	90	-
JL	1121	1122	1	1	1	51	-

* RR (Reading Recovery), LD (learning disability), EAL (English as an additional language)

Discussion and Conclusion

Analysis of the MAI growth point data for the cohort of 3277 Grade 1 children found that between 10% and 27% of children were vulnerable in each domain when measured against the *On the Way* growth points. Higher proportions of children (19% to 35%) were vulnerable in each domain by Grade 2. This finding likely reflects the more challenging curricula in Grade 2, but also suggests that teachers may struggle to provide classroom environments and teaching that enable all children to thrive. This was most pronounced for Place Value in Grade 2 once the *On the Way* growth point increased to Growth Point 2: read, write, order and interpret 2-digit numbers. Achieving this growth point was challenging for about one-third of children at the beginning of Grade 2. Overall, the prevalence of vulnerability in mathematics learning for children in both Grade 1 and Grade 2 suggests the need for classroom teachers to consider approaches to further enhance children's mathematics learning. This may require a more sophisticated image and vision of what high-quality teaching looks like, and belief that all their students can engage in rigorous mathematical activity if given appropriate support (Cobb et al., 2018).

The EMU intervention program aligns with the five key features recommended by the National Joint Committee on Learning Disabilities (2016), and the five effective teaching practices identified by Jitendra (2013) to accelerate the mathematics learning of students who currently struggle. The results reported in this paper suggest that the students who participated in the EMU program progressed in their learning at a greater rate than for Grade one students overall, and were vulnerable in fewer domains 12 months later than they were at the beginning of Grade 1. However, 75% of the EMU students remained vulnerable in at least one whole number domain at the beginning of Grade 2, and these domains were most likely Counting and Place Value. The results also demonstrate that the EMU students varied greatly in the combinations of domains for which they were vulnerable, and in their progress after 12 months. This finding highlights the complexity of providing supplementary supports for currently struggling students

Overall, these findings may help teachers and researchers be clearer about the prevalence of mathematical vulnerability for young children, and the need for further insight about the

type and duration of supplementary supports that can most effectively assist them to thrive mathematically. This is a complex and important endeavour that warrants further research.

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