Holdfast Partnership Project Report

Grades 3 and 4, 2015

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Contents

1 | Executive summary

This Partnership Project provided a cost-effective approach to rapidly improve student numeracy results through a combination of professional learning and resource provision. This project showed a significant change in teacher beliefs regarding the nature of mathematics teaching and learning, which led to change in practice and highly-significant growth in student results.

Student data obtained using PAT M testing showed an effect size (Cohen's d) in six months of 0.69, which is equivalent to that normally experienced by highly-effective teachers in 12 months. This improvement was statistically significant at over 99.99%. Other measures of growth were consistent with these findings, with an effect size of 0.7 or higher.

Important factors contributing to this growth include:

- <25 hours of professional learning with an external consultant, using conceptual change theory to address underlying beliefs about effective practice
- Provision of resources for teachers to select from and adapt which made use of challenging problems and conceptual change theory to directly address student understanding of key mathematical concepts

The low-cost and high-effect size of this project indicate that it is easily scalable, with resultant growth in Numeracy results evident State-wide within two years.

2 | Project Aims and Rationale

According to the Department for Education and Childhood Development (DECD), several distinct advantages underpin the push towards collaborative partnerships. These include, "the exchange of practice and expertise, reduced isolation, collaborative professional development and facilitation of knowledge sharing and school improvement."[1] As part of this movement, local schools have been encouraged to work together on projects to facilitate professional learning between teachers at different locations, thereby improving numeracy outcomes for students.

The Holdfast Partnership Project for Grades 3-4 commenced in February 2015, engaging mathematics consultant Tierney Kennedy to work with selected Grade 3 and 4 teachers from across the Partnership. The aims of the project included:

1. To address TfEL domains 3 and 4, targeting mathematics and numeracy. More specifically within TfEL, to address the following requirements[2]:
   - 3.2 Foster deep understanding and skilful action
   - 3.3 Explore the construction of (mathematical) knowledge
   - 4.1 Build on learners' understandings
   - 4.3 Apply and assess learning in authentic contexts

2. To address the recent policy developments for Great Start, Strong Foundations and Powerful Learners[3], more specifically:
   - Identify and implement effective intervention strategies for students not achieving minimum standards
   - Create and equip powerful learners – to solve problems and think innovatively in order to deal with the issues and unfamiliar situations that constantly arise in a rapidly changing world
   - Extend professional knowledge, understanding and practice in numeracy through building on existing professional learning, coaching and mentoring practices

3. To address Partnership-specific concerns regarding:
   - Overall NAPLAN and PAT Maths numeracy performance
   - Student apparent lack of understanding of key number concepts
   - Teachers' anxiety regarding mathematics
   - Teachers' lack of confidence in their own mathematical ability and their ability to teach mathematics effectively
   - Effective assessment of student understanding rather than fluency
   - Effective use of problem-solving in mathematics

4. To create a sustainable and scalable training approach that can be applied across multiple partnerships that directly addresses needs of teachers, both individually and in groups, with demonstrated improvements in student results.

3 | Background to the Approach

Fleming & Kleinhenz (2007) argue that "*improving student learning and achievement is the core business of schools*"[4] with teaching quality singled out by the OECD as "*the single biggest in-school influence on student learning*".[5] The 2007 McKinsey Report, which identified features common to the world's top-performing school systems, takes this further, arguing that the quality of an education system simply cannot exceed the quality of its teachers.[6] These findings led the Australian Government to declare that the first priority for the COAG reform agenda is "*Raising the quality of teaching in our schools*".[7]

Hattie's (2009) meta-analysis of over 800 major studies of educational effectiveness used Effect Size (Cohen's d) to directly compare the effectiveness of various teaching approaches. Average teachers are thought to have an effect size in 12 months of between 0.15 and 0.35. An effective approach has an effect size of 0.4 or greater. Unfortunately, Hattie also notes that "variation in teacher effectiveness is much greater for mathematics than for reading outcomes"[8]. While teaching quality may be at the forefront of educational achievement, this variation has a significant impact on student learning and needs to be addressed if teaching is to be effective.

In a landmark study into effective teaching, Askew, Brown, Rhodes, Johnson & William (1997) found that the most effective teachers, as measured by improvement in student results, combined aspects of different approaches into what they termed a "Connectionist Disposition"[9]. Effective teachers were able to select from a range of strategies, and use these to make connections for their students in order to help them understand mathematics.

> *Teachers who gave priority to pupils acquiring a collection of standard arithmetical methods over establishing understanding and connection produced lower numeracy gains… Teachers who gave priority to the use of practical equipment rather than developing effective methods, and delayed the introduction of more abstract ideas until they felt a child was ready for them, also produced lower gains.*
>
> Askew et al., 1997, pp.2-3

As part of this study, Askew et al., identified that effective teachers explicitly identified and worked on student misunderstandings as part of their lessons. This point of difference was also identified in the 2009 OFSTED report[10], which explained that "the best teachers focus on pupils' errors as a learning point. They spot the significant misconceptions which are illuminated by pupils' mistakes" (Ofsted, 2009, p.41). Hansen (2014) also promotes this approach, finding that "effective teaching of mathematics involves planning to expose and discuss errors and misconceptions in such a way that children are challenged to think, encouraged to ask questions and listen to explanation, and helped to reflect upon these experiences." (p.18)[11]

In a recent study which applied a Connectionist lens to examination of teacher practice, Kennedy (2015), found that student misconceptions and alternative conceptions could be effectively

addressed within a challenging problem by applying conceptual change theory. This paper identified a questioning model that enabled students to confront their own conceptions and change their own minds[12]. Within this project, conceptual change theory was used in professional learning to change teacher beliefs as well as being used by the project teachers to address student conceptions within their own classes.

Working on the principle that "it is what the student does that is more important in determining what students learn than what the educator does" (Reaburn, Muldoon, & Bookallil, 2009, p. 821), this project focused on student actions and thoughts rather than simply on teacher actions. Challenging problems were presented to students prior to explanations, enabling students to begin building connections through exploration. These problems also served as diagnostic tasks for identifying misconceptions and alternative conceptions, at which point teachers in the project used Kennedy's questioning model to induce cognitive conflict and enable students to confront their own conceptions. This approach was used for two to three lessons per week by teachers in the project, with the remaining lessons spent using more traditional methods.

4 | Methodology

4.1 Professional Learning

Within this project Teacher Professional Learning (d= 0.5)[13] combined with resource provision formed the basis for change in practice. While Garet et. al (2001) indicate that more than 80 hours of professional development are likely to be needed if there is to be any significant change in practice[14], this project did not have scope for that amount of time with a consultant. Instead, teachers spent four days with the consultant (less than 25 hours), time trying out the approach in their own classes and additional follow up with a local project leader. In order to maximise effectiveness, Professional Learning was constructed around observing and analysing classroom practice, with conceptual change theory used to influence teacher beliefs. An initial two-day course in term 1 was followed by two single-day professional learning experiences in terms two and three. A third single day in term four enabled reflection and examination of results by all participants. Finally, teachers participated in online learning modules created for this project which focused on three key number concepts: Quantity, Partitioning and Place Value.

This included a two-day course which included:

- Direct observation of a live problem-based lesson using a modification of the Piagetian-based strategies (d=1.28[15]) of Accommodation and Assimilation to challenge students to solve problems (d=0.64[16]) whilst diagnosing and addressing underlying misconceptions.
- Deconstruction of the feedback (d=0.73[17]) obtained on student conceptual understanding, including analysing observed misconceptions and correlating these with research into key number concept difficulties.
- Deconstruction of questioning techniques used in the demonstration lesson, including use of a five-stage model for creating conceptual change using cognitive conflict[18], and linking these with the Australian Curriculum Proficiency Strands.
- Immediate application of the strategies by teachers to teach groups of students on the second day of the course, including planning, implementing and self-reflection.
- Analysis of NAPLAN tests, including links with the Australian Curriculum proficiency strands, misconceptions and direct observations of student understanding.

Follow up days included more observation of live classroom practice, joint planning, examination of student sample assessment and further work on key number concepts.

Data was gathered using Likkert-style surveys to examine the impact that the course had on teacher beliefs regarding:

1. The nature of mathematics
2. Mathematical ability
3. Effective teaching practices
4. The nature of problem solving

This survey was supplemented with qualitative data, including free response items, teacher journal entries and reflections by significant change stories.

In-person Professional Learning was also complemented by the provision of resources for teachers to use for two to three days per week. These resources provided similar lesson structures and resources to those used during the two-day training course. The lessons followed the same questioning structure identified by Kennedy (2015), and provided ongoing professional learning for teachers throughout the course of the project. Further details are included in section 4.3 below.

4.2 Student Achievement Data

Baseline data was gathered on student achievement in three different ways. These included:

- PAT M Tests from ACER
- Place Value Diagnostic Test developed by the researcher[19]
- Proportional Reasoning Diagnostic Test developed by the researcher[20]
- NAPLAN Tests from ACARA for grade three students.

Effect Size (Cohen's d) of student improvements was compared with the scale of effect used in Hattie's (2009) meta-analysis.[21] As students sat NAPLAN at the beginning of the project and will not sit this again for two years it was not possible to measure growth in this area.

PAT M Tests from ACER

One of the schools in the Partnership Project had their Grade three and four students sit an online PAT M test in May 2015 and again in October 2015 (just under six months). The tests were marked by ACER, with scores used to calculate effect size as shown in the results. Results are presented for the students of teachers directly involved in the project (n=75). Project teachers also went and shared their learning with other grade three and four teachers from the same school, so results from all of the grade 3-4 students are also presented (n=181).

Place Value Diagnostic Test

A diagnostic test examining student understanding of three key number concepts related to Place Value (Quantity, Partitioning and Relative Size) was administered to all students in the project before intervention and again three months later (n=384 for both tests). Answers were provided to teachers. Marking was moderated and the marking scheme discussed at the second Professional Learning session to ensure consistency.

Proportional Reasoning Diagnostic Test

Following the three month Place Value Intervention, a diagnostic test was administered to all students whose teachers were still in full-time teaching (n=253). Several teachers were unable to complete this phase of the project due to (1) changing schools, (2) long-service leave, or (3) promotion to an administration role. Following the initial testing, teachers undertook an intervention program for 2-3 days per week in both multiplicative thinking and proportional reasoning. After three months the testing was repeated and the growth measured using the process outlined above.

4.3 Provision of Lesson Plans

Sullivan et al. (2014) established that providing lesson plans to busy teachers created an opportunity for ongoing professional learning while still enabling teachers to make active decisions regarding implementation[22]. In order to address the Partnership Project teachers' anxiety regarding mathematics and their own abilities to both understand and teach mathematics well, it was therefore decided to provide lesson plans and resources for teachers to use and adapt throughout the project. Teachers were initially asked to use the lesson plans at least once per week for the first half of the project, with a move to three times per week for the second half. A suggested work program was provided for a few weeks, but otherwise the use of the resources was determined by each individual teacher.

Resources were used from two separate series, both written by Tierney Kennedy:

- Interventions in Mathematics
- Back-to-Front Maths

One of the books from the Interventions series, *Fixing Misconceptions in Place Value to 1000*, was created specifically to address the needs of the project teachers as well as more generic needs identified by the author when consulting in South Australian schools. This was additionally supported by the production of online learning modules on the same topic which were used by teachers throughout the project duration. The Interventions series directly addresses the Great Start, Strong Foundations and Powerful Learners[23], mandate to identify and implement effective intervention strategies for students not achieving minimum standards.

The second series selected, *Back-to-Front Maths*, has been well-reviewed in the AAMT publication *Australian Primary Mathematics Classroom* (19 (3) 2014), with a recommendation for coordinators to consider "when revitalising maths teaching and implementing the *Australian Curriculum*" (p.39). This series was selected as it uses the Launch, Explore, Summarise[24] structure suggested by Lappan et al. (2006) - it is developmentally sequenced to foster deep understanding by diagnosing learners' existing understanding, constructing bridges to new concepts and connecting and generalising that knowledge to broader contexts. This directly addresses TfEL domains 3 and 4, targeting mathematics and numeracy.

5 | Results

5.1 Effectiveness of Professional Learning for Teachers

On the first day of training 27 participants were present, however on the second day only 22 participants were able to come due to other training commitments. Of those present, 17 completed the 6-month project and also completed pre and post surveys in Likkert style regarding the training, designed to measure teachers' beliefs on the following four domains:

- the nature of mathematics,
- mathematical ability,
- effective teaching practices, and
- the nature and use of problem-solving.

Each question gave a belief statement, asking teachers to respond on a five-point scale between strongly agree (1) and strongly disagree (5). These paired responses were analysed using student t-tests for statistical significance, with the effect size also calculated. To ensure the validity of the test two control statements were included. These statements were "I didn't really feel like I understood maths while I was at high school", and "Personally I would prefer to teach literacy than numeracy". Data analysis shows that changes in teacher beliefs in these two areas were not statistically significant. This indicates that the changes to the other statements can be considered valid.

The Partnership Project was found to have a significant positive effect on all four domains. The effect size ranged from 0.52 to 1.35, with a statistical significance of over 95% in all areas. Findings are presented in the table below for each domain:

Statement	Effect Size (Cohen's d)	T stat	P (T<=t) two-tail	Stat sig.
Domain 1: the nature of mathematics				
Maths is mostly about memorising rules, formulae and content.	0.68	-3.41	0.004	99%
Domain 2: mathematical ability				
Maths ability is fairly well fixed – you are either good at maths or you aren't.	0.54	-2.75	0.014	95%
Domain: effective teaching practices				
Teaching is most effective when: we give a clear explanation of how to solve a question, provide practical examples and get students to practice what we have shown them until they can repeat it.	1.35	-4.24	0.0006	99.9%
Understanding in maths is generally developed through memorisation.	0.71	-3.39	0.004	99%
Children who have difficulty with maths need to focus on memorising basic facts and practicing skills	1.21	-4.37	0.0005	99.9%
When students don't understand something then it is my job to tell them again until they can remember it.	0.73	-3.04	0.008	99%
When students don't practice their skills frequently then they forget maths that they used to really understand.	0.52	-2.86	0.011	95%
Domain: the nature and use of problem solving				
Problem-solving is mostly applying maths that you know to word problems	1.02	-3.79	0.002	99%
Solving challenging problems is more important for students who need extending rather than those who need support	0.86	-2.52	0.023	95%

5.2 PAT Maths Growth

One school participating in the Partnership project had their students sit PAT M testing in May and again in October. While this represents only one of the project schools, the results obtained by this school with regards to the Place Value Intervention and the Proportional Reasoning Intervention shown in the sections 5.3 and 5.4 were consistent with others in the project. The data obtained through PAT testing can therefore be considered representative for all participating schools.

Results from 75 students with teachers directly involved in the project were analysed in detail, with additional data from 181 students provided in the section that follows.

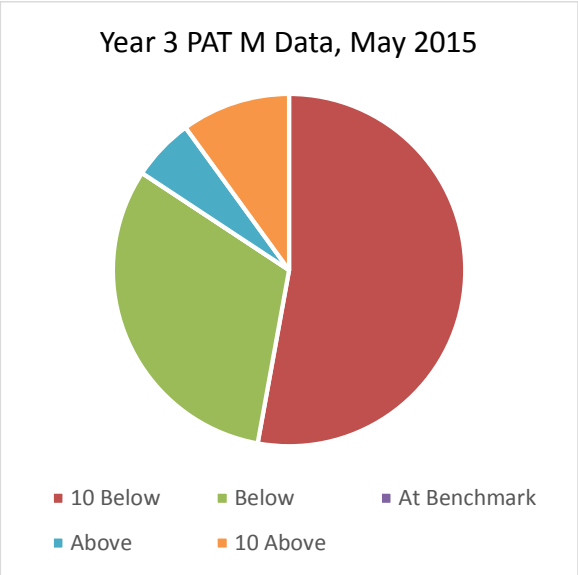
PAT Data for those directly involved in the project	May	October
Mean	15.48	19.88
Standard Error	0.78	0.71
Median	15	20
Mode	11	14
Standard Deviation	6.74	6.13
Sample Variance	45.42	37.59
Count	75	75
t Stat	-5.80	
P(T<=t) two-tail	0.0000002	
Z stat	-4.18	
Effect Size	**0.69**	
Statistically significant at	**99.99%**	

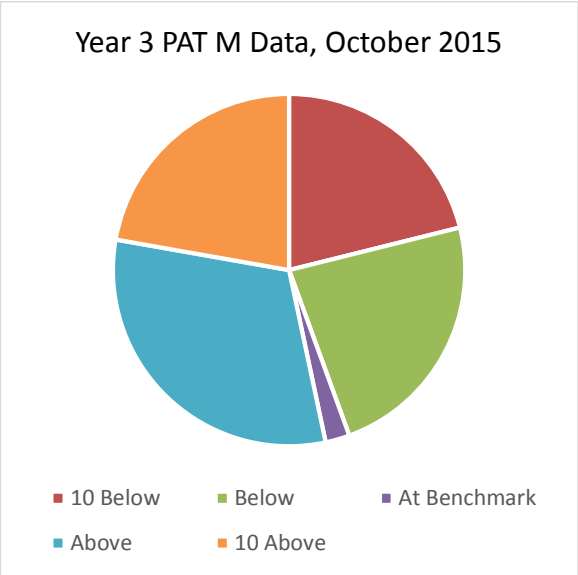
This shows an overall effect size of 0.69 in the six month period between May and October. This is equivalent growth to that normally achieved by a highly effective teacher in 12 months[25].

The teachers from the Partnership Project also went back and shared their learning with all other grade three and four teachers from their school. This included 90 students from grade three and 91 students from grade four. The results from these students were also analysed to determine how effective the sharing of information was across the cohort. The following table and graphs show PAT Maths results between May and October across all 181 students:

PAT Data for all 181 students	May	October
Grade 3 Students at or above the bench mark	16%	56%
Grade 3 Students at 10 above bench mark	10%	22%
Grade 4 Students at or above the bench mark	41%	65%
Grade 4 Students at 10 above bench mark	9%	20%
Effect Size	**0.48**	
Statistically significant at	**99.99%**	

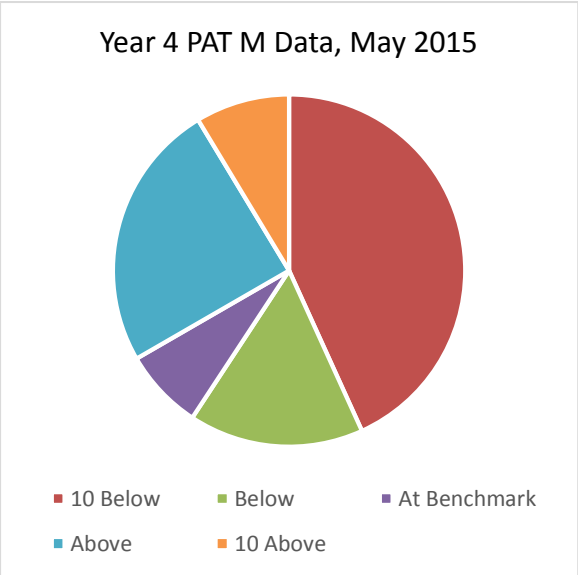
Grade 3 PAT M Growth for 90 Students, May to October 2015

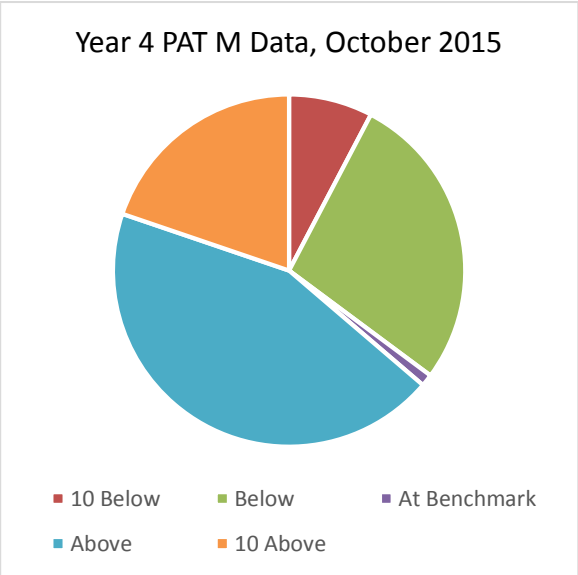




The growth in student results for grade three was found to be consistent across all sub-sections of the data.

Grade 4 PAT M Growth for 91 Students, May to October 2015



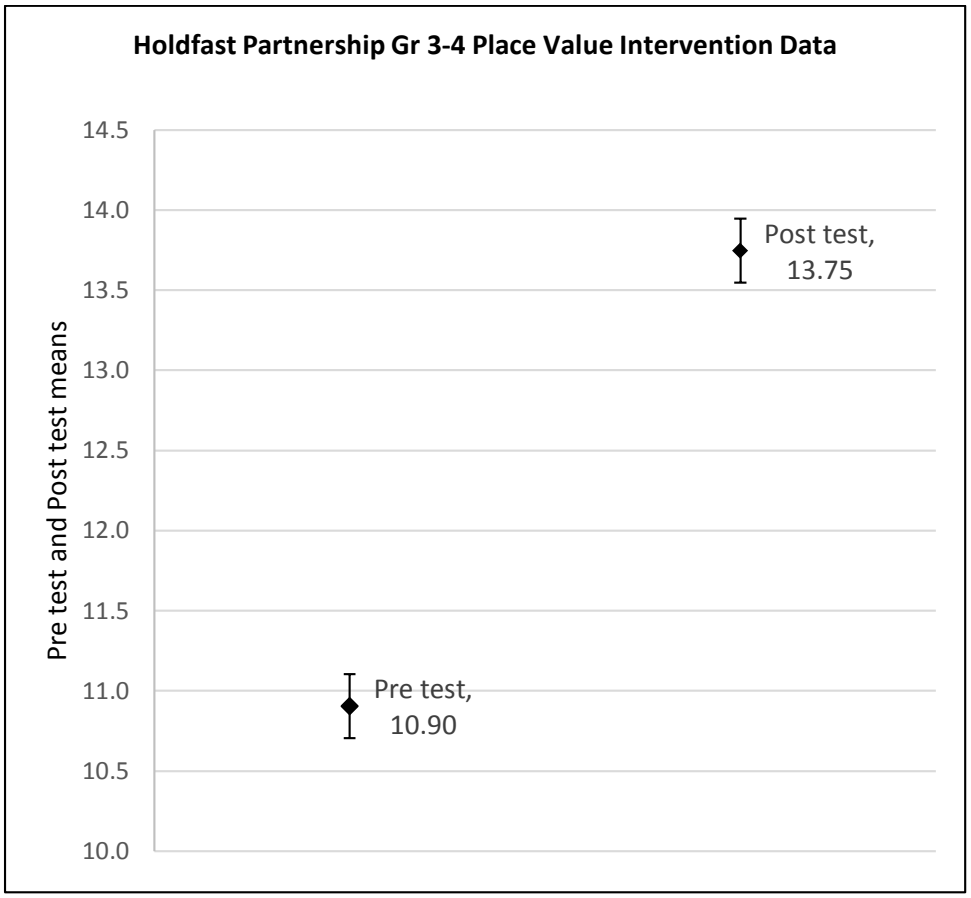


The growth in student results for grade four was found to be consistent across all sub-sections of the data.

5.3 Place Value Intervention Results

Results from 384 students were analysed. With an effect size of 0.77 this project is considered highly successful. Findings are included below in both tabular and graphical formats.

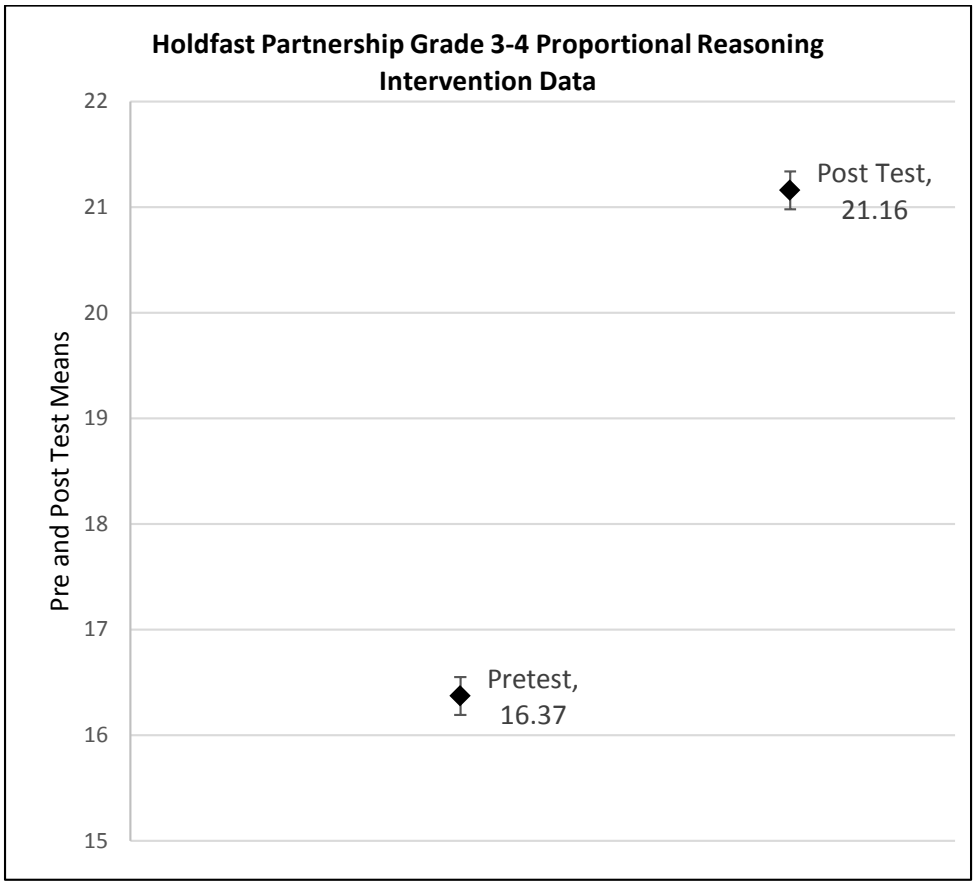
	Pre Test	Post Test
Mean	10.90	13.76
Standard Error	0.20	0.19
Median	11	14
Mode	12	17
Standard Deviation	3.83	3.63
Sample Variance	14.67	13.15
Count	384	384
t Stat	-18.68	
P(T<=t) two-tail	8.01E-56	
Z Stat	-10.61	
Effect Size	**0.77**	
Statistically significant at	**99.99%**	



5.4 Proportional Reasoning Intervention Results

Results from 253 students were analysed. With an effect size of 0.70 this project is considered highly successful. Findings are included below in both tabular and graphical formats.

	Pre Test	Post Test
Mean	16.37	21.16
Standard Error	0.36	0.50
Median	16	20
Mode	17	18
Standard Deviation	5.78	7.99
Sample Variance	33.40	63.88
Count	253	253
t Stat	-14.65	
P(T<=t) two-tail	1.38E-35	
Z stat	-7.72	
Effect Size	**0.70**	
Statistically significant at	**99.99%**	



6 | Conclusions and Recommendations

Often it seems that growth in Numeracy results is difficult to obtain, particularly where teachers are resistant to change or anxious about their own mathematical understanding. Growth in student results is reliant on changing teacher practices, which is in turn reliant on changing teacher beliefs. As these beliefs are often impervious to change[26], current educational research offers very little evidence about what students learn as a result of changed practices[27]. This Partnership Project sought to address all of these issues in combination and to determine whether this approach could be effectively scaled-up without much input from external consultants (under 25 hours).

The results from this Partnership Project indicate that providing a combination of highly-effective professional learning with lesson plans that use conceptual change theory to target underlying misconceptions within a challenging problem can result in significant change in teacher beliefs and in resultant student data. An analysis of student results demonstrated that the effect size of this six month project was equivalent to that achieved by a highly-effective teacher in 12 months.

Scalability

This project involved professional learning led by external consultant for only four days (less than 25 hours) prior to the final data collection with some additional time by the local project coordinator. This time is much lower than the 80 hours of professional learning considered necessary[28] to alter teacher beliefs before any changes in practice can be expected. It appears that combining highly-effective professional learning experiences with the provision of lesson plans encouraged a higher up-take of the pedagogical approach than would normally be considered achievable. This combination also kept costs low, providing a highly-effective, low-cost and sustainable way for improving student numeracy and mathematics data across multiple schools. Using only four days of the consultant's time per partnership, this approach would be easily scalable to reach 50 partnerships without involving any other non-DECD personnel, with further reach possible more consultants or by making use of online modules and webinars.

It is recommended that DECD verify the findings of this Partnership Project by repeating this approach with an additional five to ten Partnerships in 2016. If these findings prove to be consistent, it is recommended that DECD consider applying this approach State-wide in 2017, with growth in Numeracy results expected to be evident by 2018.

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