AFTER SCHOOL MATHS CLUBS: INVESTIGATING LEARNER PROGRESSION IN AN EXPANDING INTERVENTION MODEL

Debbie Stott [1], Mellony Graven[2], Nolunthu Baart[3], Gasenakeletso Hebe [4] & Zanele Mofu[5]

[1 to 5] Rhodes University

Additionally [3]EC District DoE, [4]NW District DoE, [5]EC Provincial DoE

In the context of learner reliance on using one-to-one counting methods to solve basic operation problems, this paper investigates learner progression in a common assessment across three research projects in South Africa. These projects focus on learner progression in mathematical proficiency in after-school maths clubs as part of a broader maths clubs teacher development programme that takes place over 15-weeks in the after-school club space. We argue that within the tightly focused development programme, learners make substantive progress when comparing scores in both a pre and post assessment. The three studies were conducted as multi-site case studies across three educational districts and 33 clubs, encompassing 300 learners in total. The paper contributes to a growing body of research on after-school clubs as out-of-school time interventions in South Africa.

INTRODUCTION, CONTEXT, FOCUS & SIGNIFICANCE OF THE PAPER

Much South African research points to overdependence on concrete counting strategies (see for example Fleisch, 2008; Schollar, 2008; Spaull, 2013; Taylor, 2008). South Africa currently sits with a crisis in primary education where learners are still bound by using concrete strategies to solve mathematics problems. Many learners are ‘trapped’ in using concrete one-to-one counting methods or dependence on algorithms without understanding. The result is an absence of flexibility and fluency with both numbers and operations (Graven & Stott, 2016). It has been noted that such practices hinder a coherent development of number sense and efficient arithmetic strategies (Graven, Venkat, Westaway & Tshesane, 2013).

Phase I of the South African Numeracy Chair (SANC) project focused on establishing after-school maths clubs for primary learners in Grahamstown schools as a new initiative (see Graven, 2016a). Findings from this phase have been reported on by the project team and show that the clubs provide enabling spaces for both recovery and extension of mathematical proficiency in learners as these spaces are free from several contextual constraints that teachers face in their classrooms. Additionally, the SANC project team hypothesise that the clubs provide a safe space for trying new pedagogical approaches for the teachers and for ourselves and building confidence in these approaches. The model for the clubs has evolved over the last five years as reported in Stott and Graven (2013) and Stott (2016).

Local and national interest in the after school maths clubs has grown rapidly which comes with the challenge to engage more deeply with issues of the extent to which clubs run in districts beyond the SANC project focal area are of value and sustainable and can be ‘scaled up’. Graven (2016b) however, highlights several issues associated with expanding or “scaling up” local development projects to both provincial and national levels. She argues that rather than scaling up, partnering with provincial education officials, in ways that proactively communicate the theory of action underpinning our interventions is a necessary step in enabling national interventions and localized interventions to both adapt to one another and to be transformed in ways that are responsive to the changing local and national landscape.

In 2015, leveraging such strong local relationships as highlighted by Graven (2016b), the SANC project expanded the Phase 1 club model to five local after-care centres. This expansion, while largely successful in terms of learner attendance, was not without challenges. Although club leaders from the after-care centres were trained to run clubs, the scope of the multiple aspects of the club design run by project team members seemed too broad for communicating to facilitators – many of whom had little or no teacher training (let alone numeracy teacher training). We have noted that key successes across all the club research to date pointed to providing support for learners to progress from concrete calculation methods to more efficient and fluent methods based on a progression model. Thus, we simplified the club design with a clearer focus to alleviate some of the challenges encountered by the after-care centres.

In 2016, progression became the major focal element for the SANC project’s maths club teacher development programme called “Pushing for Progression” (PfP). Working from this premise, the programme is devised from activities that have been used in the clubs since 2011 and looks to develop learner progression in the 4 basic operations over a 15-week period (Graven & Stott, 2016). The SANC project team have partnered with district and provincial officials, who are also part of our research team to leverage strong relationships in provinces and districts to support teachers in setting up and running clubs of their own. Teachers are invited to attend a series of workshops, which aim to provide them with resources for assessment and club activities as well as an orientation to why it is important to focus on progression. Further, in the workshops the team work with teachers to understand how to progress the learners from concrete methods to more efficient ones. It thus aims at both learner and teacher / facilitator development. During 2016 this programme was expanded to four districts in three South African provinces.

Thus the rationale for this paper is to report on learner progression in *three* of those four districts, all with the common aim to investigate the *changes* evident in learners' mathematical proficiency over the 15-week period of club participation. The common empirical field for the three projects in this paper is thus the tightly focused 15-week teacher development programme in the after-school maths club space.

The research is important because it allows us to report on learner mathematical progression through an intervention model that is rapidly expanding. Additionally, the clubs that were part of this research have been run by teachers and not by the SANC project team, which talks to an expanding sphere of influence beyond the project. Finally, the research contributes to a growing body of research on after-school clubs as out-of-school time interventions in South Africa as well as primary mathematics teaching and assessment.

THEORETICAL FRAMING AND LITERATURE REVIEW

Mathematically, the primary emphasis in the PfP programme is on learner progression in relation to procedural fluency and conceptual understanding as two of Kilpatrick, Swafford and Findell's (2001) five strands of mathematical proficiency. Conceptual understanding is the comprehension of mathematical concepts, operations, and relations, whilst procedural fluency is skill in carrying out procedures flexibly, accurately, efficiently, and appropriately. A number sense approach can be useful to think about the relationship between these two strands. A child with number sense has the ability to work flexibly with numbers, observe patterns and relationships and make connections to what they already know, to make generalisations about patterns and processes (Anghileri, 2006). Burns (2007) notes that if learners think there is only one correct way to work something out, they will focus on learning how to apply that single method, rather than thinking about what makes sense for the numbers they are working with.

In our respective work, we have noted for example, that learners are often weak on number bonds. The bonds of 5 and 10 are often not recalled automatically and learners use counting on by ones or their fingers to work out for example the answers to 2 + 8 or 2 + 98. Their grasp of basic number sense and basic bonds is severely limited and few of the learners seemed to have strategies other than using their fingers to solve problems. Although they can be accurate using these methods, they were often slow at arriving at an answer to a problem, especially when the number ranges increase. In later grades, we note that learners often learn procedures for calculating in a rote manner. As many mathematics educators note (e.g. Askew 2002; Bobis 2007; Burns

2007), learning these without understanding can be detrimental to learners. Understanding is essential. Bobis (2006) indicates ‘the greater the degree of understanding, the less practice that is required to obtain fluency” (p.25).

Thus there is a need to develop procedural fluency and conceptual understanding by exposing learners to as many methods of solving problems as possible. Rittle-Johnson and Alibali (1999) argue that, “conceptual understanding plays an important role in procedure adoption and generation. However, it seems likely that this relationship is not a unidirectional one. Instead, conceptual and procedural knowledge may develop iteratively, with gains in one leading to gains in the other, which in turn trigger new gains in the first” (p. 176).

The PfP programme, as mentioned above, has this kind of focus. However, in this paper, we present findings from a 4 operations assessment (described later) and the score comparisons between a pre and post assessment. Thus, the focus here leans more towards reporting on the learners’ progress with regards to *procedural fluency*. As indicated later, the assessment also allows both the participating teachers and researchers to gain an understanding of learner progression in conceptual understanding, but this aspect is not reported on here.

Theoretically, all three studies work broadly within a social constructivist perspective of learning in relation to interpreting learner understanding and progression, derived primarily from Vygotsky’s work. Vygotsky (1978) conceptualised development as the transformation of socially shared activities into internalised processes in his “general genetic law of cultural development” arguing that higher mental functioning appears first on the social level and then on the individual level.

> Every function in the child’s cultural development appears twice: first, on the social level, and later, on the individual level; first, between people ... and then inside the child. This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher [mental] functions originate as actual relations between human individuals” (Vygotsky, 1978, p.57).

This perspective views learning as a process whereby individuals construct their understanding from their experience and from their environment in which a knowledgeable other is a part of. Vygotsky (1978) describes the dialectical nature of learning and development thus:

> learning awakens a variety of internal-development processes that are able to operate only when the child is interacting with people in his environment and in cooperation with his peers. … learning is not development; however, properly organised learning results in mental development and sets in motion a variety of developmental processes that would be impossible apart from learning. Thus learning is a necessary and universal aspect of the process of developing culturally organised, specifically human, psychological functions (p.90).

Vygotsky argued that learning does not happen in isolation, learning and teaching take place in the social plane and in the interactions between participants, before it is internalised into the individual.

In the context of the research projects discussed here, mathematical proficiency progression is the key focus through participation in clubs. Thus, we view the development of proficiency through the social interactions that take place in the clubs, which is finally internalised for each individual learner, manifesting itself in what the learners are able to do mathematically at the end of the 15-week period.

METHODOLOGICAL APPROACH

Given the focus on learners' progression whilst participating in the after-school clubs, all three research studies have the same methodological focus, working from an interpretive paradigm, using multi-site case studies of their respective after school maths clubs (five clubs for Baart, 12 for Hebe and 16 for Mofu).

Although Mofu's research focus is on teacher learning, the teachers who participated in her research collected *learner* data using the same quantitative data collection instrument as Baart and Hebe (see description below), providing further cases. With their focus on learners, the case study approach used with respect to Baart and Hebe provides the opportunity to investigate in depth of shifts in learner's mathematical proficiency while they participate in after school clubs and portray, analyse and interpret the complexity and uniqueness of these real learners and the situation within the real-life context of the clubs.

EMPIRICAL FIELD AND SAMPLING FOR THIS RESEARCH

For all the regions, the broad empirical setting is the 15-week PfP programme discussed above. Each region selected a number of teachers to participate in the programme, who in turn selected learners to participate in their own club. Thus, the exact empirical setting for each region consisted of both the learners who participated in the maths clubs as well as their teachers who have attended the 15-week PfP programme and subsequently run the clubs. The focus for this paper is the mathematical proficiency of the participating *learners* as assessed in a pre-test and post-test. Table 1 below gives details of the number of teachers and learners participating in each region. The total sample size is therefore 300 learners, across the three districts.

Table 1: Research samples for each research project

Research project and region (data code)	No. learners	No. clubs (1 per teacher)	Grade
Baart - Uitenhage district (ECU)	60 (12 / club)	5	6
Hebe - Maquassi Hills district (NWMH)	144 (12 / club)	12	3

Mofu - King Williams Town district (ECK)	Gr 2: 12 (6 / club) Gr 3: 48 (6 / club)	16	2 & 3
	300	**33**	

DATA COLLECTION AND ANALYSIS

Of course, in each region, data was collected exclusively to address each researcher's particular research questions (e.g. via teacher questionnaires and interviews). However, learner progression data was collected by each teacher running a club to profile their club learners and to assess learner progression in procedural fluency over the 15-week period. Permission was gained from the teachers to use this data for each researcher's project. This learner progression data thus forms a common corpus of data across all three regions. The data were obtained through implementing a four operations instrument for assessing learner progression in mathematical proficiency (specifically procedural fluency and conceptual understanding).

This instrument assesses each of the four basic operations. Each operation consists of five sums: the sums start from single digit problems and work up to 3-digit by 2-digit problems, using carefully selected numbers which aim to illicit some kind of strategy. For addition, for example, the sums are: 3 + 4; 8 + 6; 23 + 18; 55 + 67 and 104 + 97.

The same instrument was used for all learners across all the clubs, regardless of grade. Learners were assessed at the beginning of the 15-week programme and again at the end using the same instrument. Teachers used the answers and learner responses from the instrument to profile the learners in *two* ways: using score changes over time and progression in methods used along spectra. The researchers have access to this data and will use it in the write up of their respective research reports. Across the three research projects, the data based on progression has yet to be analysed, thus the focus for this paper, is purely on the quantitative data that arises from this instrument in terms of scores and percentage point changes between those scores in the two assessments, relating back to procedural fluency.

Both the pre and post assessments were marked for correct answers to arrive at a score out of 20 for each assessment, for each learner. The overall scores, as well as individual operations scores from both assessments, were compared and *change percentages* calculated. In the findings below, we talk of change with regard to the *difference* between pre and post-assessment percentage scores, which may be negative or positive in nature. The discussion below will highlight whether the changes are negative or positive as they are presented.

Additionally, the score change percentages were analysed using frequency distribution ranges (less than 9%, 10 to 49% and 50 to 100%) in Microsoft Excel, allowing us to gauge how many learners had substantive differences in scores between the pre- and post assessment. For example: if a learner scored 20% in the pre-assessment and then scored 70% in the post assessment, the percentage point difference would be 50. Thus this learner could be considered to have made progress in the range 50-100%.

FINDINGS

In this section, to address the question of the changes evident in learners' procedural fluency over the period of club participation, we report on findings from this learner progression data for each of the three research projects. We present different aspects of change using the *scores* from both the pre- and post assessments, with a summary across all learners followed by details for each research project. 234 of the 300 learners wrote both pre- and post assessments. As indicated above, these learners were from Grade 2, 3 or 6 across the 33 clubs. Other learners were absent from clubs on the day of either the pre or post assessment.

For all learners across the grade range over the 15 weeks, all operations showed positive change (Figure 3). Multiplication and division (with 25% and 24% respectively) were the biggest areas of change. These changes indicate that more questions were accessed and answered correctly in multiplication in the post-assessment, than in the pre-assessment. A similar picture is indicated for division.

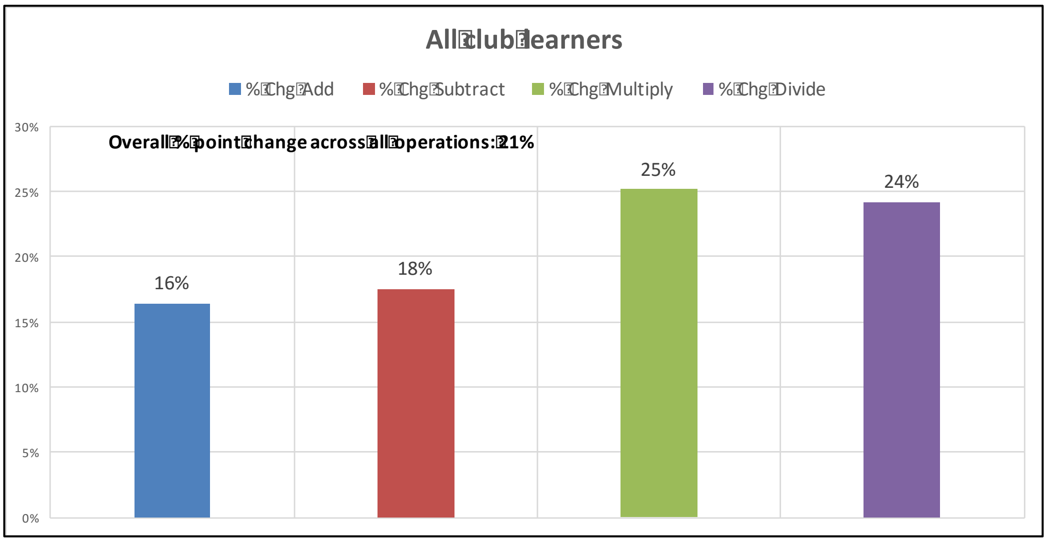

Figure 3: All club learners – Overall average % point change for each operation (rounded to 0 decimal places)

Overall, the average percentage increase for all 4 operations was 20.77%, increasing from a 40.36% average score in the pre-assessment to a 61.13% average score in the post-assessment. Table 2 below shows the percentage point change for each group of learners in each research project. The Grade 3's in ECK (see Table 1 for codes), show the biggest overall percentage point change, with a 70.21% average score after 15-weeks, indicating that these learners improved by 28.85 percentage points. The Grade 6 learners in ECU show a 24.5-percentage point improvement.

Table 2: Pre- and post-assessment averages by research project

Research project (Region)	**Pre-assessment Average**	**Post-assessment Average**	**Overall % increase**
ECK-Gr2	43.33%	50.83%	7.50%
ECK-Gr3	41.35%	70.21%	28.85%
ECU-Gr6	36.83%	61.33%	24.50%
NWMH-Gr3	41.49%	58.29%	16.97%
Average	**40.36%**	**61.13%**	**20.77%**

We turn now to look at improvement by average percentage ranges (Table 3) using frequency distributions based on score percentage changes. For all the learners assessed, 74.4% (64.1% in 10-49% range and 10.3% in the 50-100% range) of the learners achieved an increase over 10% in the post-test compared to the pre-test. This means that 174 learners improved their scores by 10% or more. Notably, 10.3% of the learners improved their scores by 50% or more (50-100% range), indicating that these 24 learners were able to correctly answer 10 or more questions than they did in the pre-assessment.

Table 3: Improvement by average percentage frequency distributions

% ranges	No. of learners	% of learners
<9%	60	25.6%
10-49%	150	64.1%
50-100%	24	10.3%
	234	**100.0%**

RESULTS FOR EACH RESEARCH PROJECT

For the Grade 2 learners in the King Williams Town district (Figure 4 below), the biggest average percentage point changes were in multiplication (15%) and addition (13%). It is important to note that at Grade 2 level, there is also a 2% change in division, meaning that although we would not expect Grade 2 learners to be able to answer more than the most basic division question, some of the Grade 2 learners tried some of the harder questions in the assessment and correctly answered some of the five division problems.

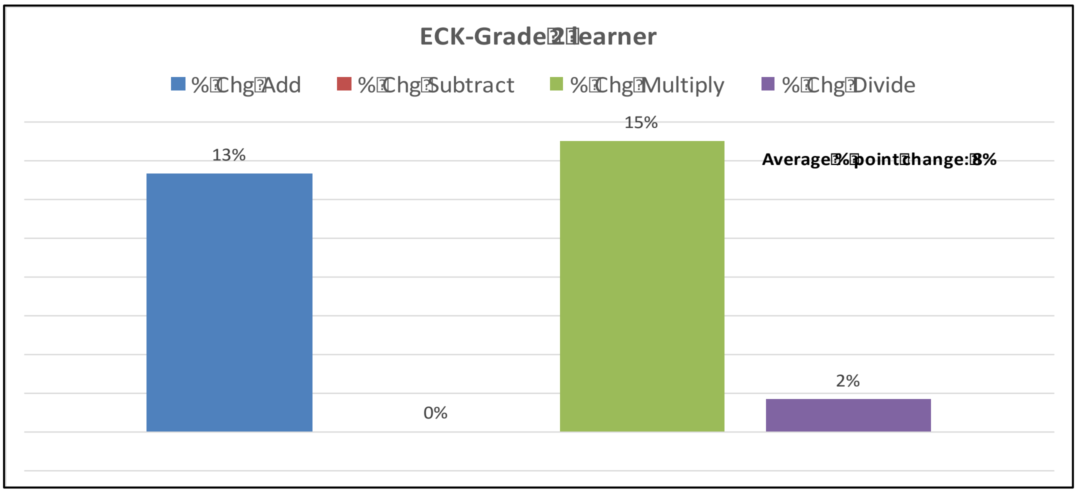

Figure 4: ECK-Grade 2 Average % point change for each operation

For the Grade 3 learners in the King Williams Town district (Figure 5 below), the biggest average percentage point change was in division (44%), although there are pleasing changes across all operations. This significant 44 percentage point change reveals that these Grade 3 learners were able to access and correctly answer 2 or more of the division problems in the assessment.

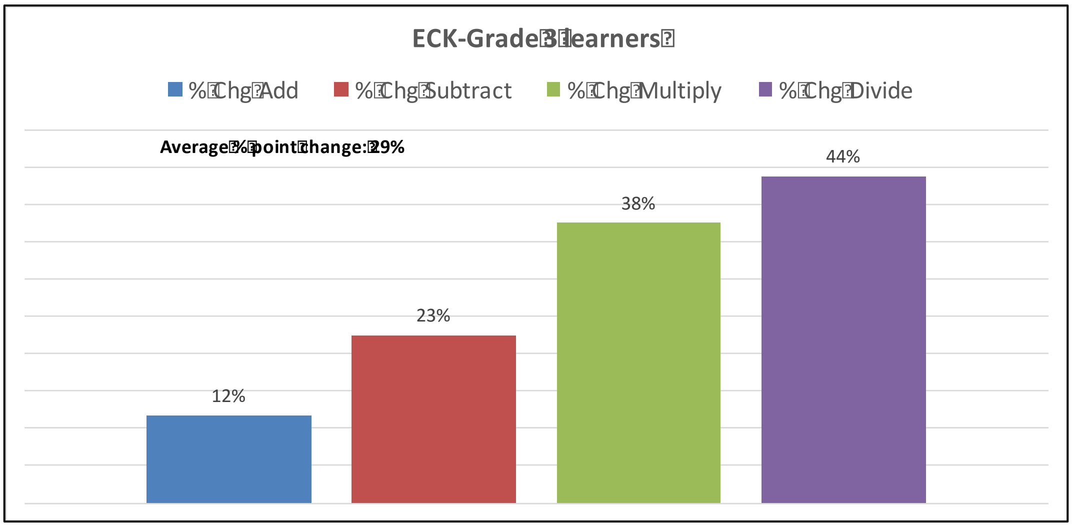

Figure 5: ECK-Grade 3 Average % point change for each operation

For the Grade 3 learners in the Maquassi Hills district (Figure 6 below), the biggest average percentage point change was in multiplication (20%), although there are pleasing changes across all operations. Again, this shows this group of Grade 3's being able to access and successfully complete more of the multiplication questions than before.

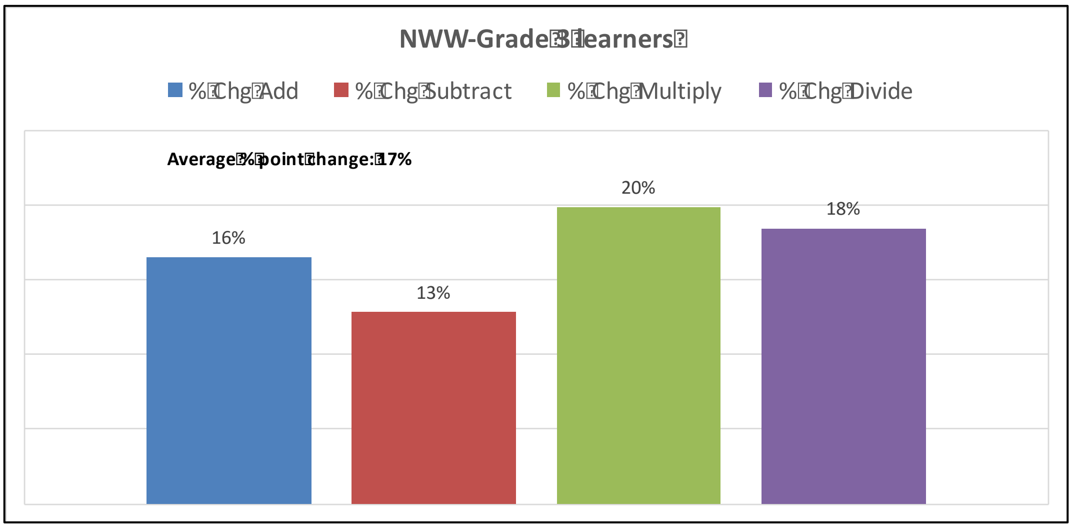

Figure 6: NWMH-Grade 3 Average % point change for each operation

For the Grade 6 learners in the Uitenhage district (Figure 7 below), the biggest average percentage point change was in multiplication (27%), although there are pleasing changes across all operations, with an overall average change of 25 percentage points across the four operations. This reveals that learners on average successfully completed five more questions (5 out of a possible total of 20 is 25%) in the whole post-assessment.

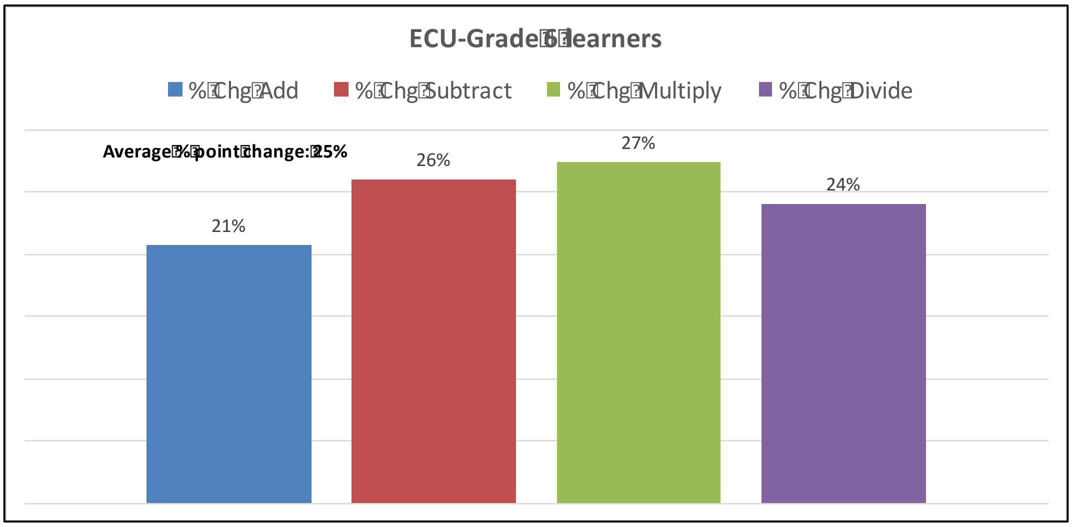

Figure 7: ECU-Grade 6 Average % point change for each operation

DISCUSSION AND CONCLUDING REMARKS

The results above are pleasing given the relatively short (15-week) intervention period. However, it is difficult to compare this improvement as we do not have similar data of the learners in these schools for the same period who did not participate in the intervention i.e. we have no control groups. However, the SANC project 2015 Indicators Report shows data for 8 schools that participated in a teacher development programme. Using the same instrument as discussed in this paper, three cohorts of learners were assessed in Grade 3 and again 12 months later in Grade 4 in 2011-2012; 2012-2013 and 2013-2014. For each cohort, the overall average increases for the learners on the same pre and post assessments over a 12-month period were 11.05%, 11.29% and 11.35% respectively. The overall average percentage point change of 21% from the learners in the PfP programme intervention over only 15 weeks were thus substantively more than this.

It is also encouraging to see the progress of these club learners over a relatively short time, in clubs run by teachers rather than the SANC project team or researchers. The clear emphasis on progression in the 4 basic operations in the PfP programme has perhaps contributed to this marked progression. Furthermore, it is pleasing that these average percentage point results are across districts / areas that are geographically far away from Grahamstown where the SANC project is based. These points to the possibility that such results can be achieved beyond Grahamstown and to the possible expansion of the sphere of influence beyond Grahamstown.

We suggest that the targeted intervention with groups of club learners and with a clear focus on progression in the four operations was highly successful. Based on this success, we intend to continue to work with provincial and district partners to offer the PfP to more teachers in the coming years. This will enable us to increase the sample size of such research over time and to more clearly explore the usefulness of the PfP programme.

References

Anghileri, J. (2006). *Teaching number sense* (2nd ed.). London: Continuum International Publishing Group.

Askew, M., Venkat, H., & Mathews, C. (2012). Coherence and consistency in South African Primary Mathematics lessons. In T. Y. Tso (Ed.), *Proceedings of the 36th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 27–34). Taipei, Taiwan: PME.

Fleisch, B. (2008). *Primary education in crisis: Why South African schoolchildren underachieve in reading and mathematics*. Johannesburg: Juta.

Graven, M. (2015). Going back in order to go forward - recovery of mathematical foundations for intermediate phase improvement. *Journal of Educational Studies: Special Issue on Breaking Barriers Hindering Learner Performance*, 1-10.

Graven, M. (2016a). Strengthening maths learning dispositions through “math clubs.” *South African Journal of Childhood Education*.

Graven, M. (2016b). When systemic interventions get in the way of localized mathematics reform. *For the Learning of Mathematics*, 36(1), 8–13.

Graven, M., & Stott, D. (2016). *“Pushing for Progression” in number sense and fluency: Maths club development programme*. Grahamstown, South Africa: South African Numeracy Chair Project (Rhodes University).

Graven, M., & Stott, D. (2012). Conceptualising procedural fluency as a spectrum of proficiency. In S. Nieuwoudt, D. Laubscher, & H. Dreyer (Eds.), *Proceedings of 18th Annual National Congress of the Association for Mathematical Education of South Africa* (AMESA) (pp. 146–156). Potchefstroom: North-West University.

Graven, M., Venkat, H., Westaway, L., & Tshesane, H. (2013). Place value without number sense: Exploring the need for mental mathematical skills assessment within the Annual National Assessments. *South African Journal of Childhood Education, 3*(2), 131–143.

Kilpatrick, J., Swafford, J., & Findell, B. (2001). *Adding it up: Helping children learn mathematics*. Washington DC: National Academy Press.

Mofu, Z. A. (2013). *An investigation of a mathematics recovery programme for multiplicative reasoning to a group of learners in the South African context: A case study*. Rhodes University, South Africa.

Rittle-Johnson, B., Alibali M.W. (1999). Conceptual and Procedural Knowledge of Mathematics: Does One Lead to the Other? *Journal of Educational Psychology. 91(1), 175-189.*

Schollar, E. (2008). Final Report: Short version *The Primary Mathematics Research Project 2004-2007 - Towards evidence-based educational development in South Africa* (pp. 1–32). Johannesburg: Eric Schollar & Associates.

Spaull, N. (2013). *South Africa's Education Crisis: The quality of education in South Africa 1994-2011* (Vol. 27, pp. 1–65). Johannesburg. Retrieved from http://www.section27.org.za/wp-content/uploads/2013/10/Spaull-2013-CDE-report-South-Africas-Education-Crisis.pdf

Stott, D., & Graven, M. (2013). The dialectical relationship between theory and practice in the design of an after-school mathematics club. *Pythagoras*, 34(1), 29–38.

Stott, D. (2016). Five years on: Learning programme design for primary after-school maths clubs in South Africa. In W. Mwakapenda, T. Sedumedi, & M. Makgato (Eds.), *Proceedings of The 24th Annual Conference of the Southern African Association for Research in Mathematics, Science and Technology Education (SAARMSTE)* 2016 (pp. 250–260). Pretoria, South Africa: Tshwane University of Technology.

Taylor, N. (2008). *What's wrong with South African schools? In What's Working in School Development* (pp. 1–30). Boksburg, South Africa: JET Education Services. Retrieved from http://www.jet.org.za/events/conferences/What works in school development/Papers/Taylor What's wrong with SA schools JET Schools Conf final.pdf/view.

Wasserman, A. (2015*). Investigating a mathematics recovery program for assessment and intervention with groups of grade 4 learners*. Rhodes University, Grahamstown.

Wright, R. J., Ellemor-Collins, D., & Tabor, P. D. (2012). *Developing number knowledge: Assessment, teaching & intervention with 7-11-year olds*. Los Angeles: Sage Publications.

Young, C. (2016). *Adaptation of the Mathematics Recovery programme to facilitate progression in the early arithmetic strategies of Grade 2 learners in Zambia*. Rhodes University, Grahamstown.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. (A. R. Luria, M. Lopez-Morillas, M. Cole, & J. V Wertsch, Trans., M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Cambridge, Mass.: Harvard University Press.