Take up and tools: Teachers' learning from professional development focused on subject matter knowledge

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Improving the teaching and learning of mathematics in secondary schools in one province in SA, through professional development of mathematics teachers

Improving teachers MfT

Improving teaching

Impacting learning
Learner gains

Mathematics for teaching course

Lesson study

Phase 1: 2010 – 2014
Promising results

Phase 2: 2015 – 2019
Expanding reach
Consolidating "results"

Pournara, Hodgen, Adler & Pillay (2015) Can improving teachers'knowledge of mathematics lead to gains in learners' mathematics attainment? *South African Journal of Education*, 35, 3, 1 – 10.

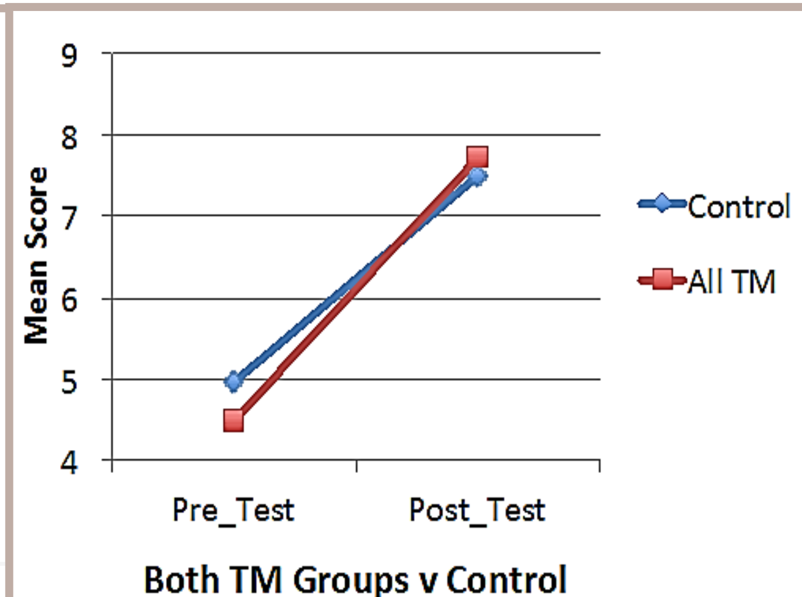
Learning gains

Investigating learning gains in relation to teachers' participation in professional development courses

Intervention group and control group of teachers

Pre- and post-test with 800 Grade 10 learners in 5 project schools over 1 year

Learners taught by teachers who had completed a TM course made **bigger gains** than those taught by teachers who had not participated in a TM course. These learners had a **lower average pre-test score** than the control group but a **higher average post-test score.**



- Learning gains study was able to link learners to WMCS participating teachers - however, the results are an average – flattening out what we know is always diverse teachers' take-up or learning from PD (e.g. Adler & Reed, 2002; Copur-Gencturk & Papakonstantinou's, 2016).

- What then have we learned about teachers' take-up from the WMCS mathematics focused PD?

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Take-up – two indicators

- Teachers' scores in mathematics assessments pre and post their PD participation

- Differences in teaching – specifically by what mathematics is made available to learn in lessons recorded before and after the course.

Two teachers' stories

- Both qualified experienced teachers – though with different trajectories into mathematics teaching
- Teaching in different secondary schools, both serving learners from poor communities
- Both participants in 2012 PD MfT course and since then over a number of years

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Ms A (T6) – came in with relative "strong" secondary maths and thrived

Teaching in her 'old' school – very poor township

Qualified teacher - 3 year secondary diploma + Advanced Certificate in Education (Maths) (4th year) (post 1998)

Pre-test 73%   Post-test 78%   (substantial progress)

2012 lesson – Equations with fractional indices

- Restricted **example space**
- **Explanatory talk:** "What you do on the left you must do on the right".

2013 lesson – Quadratic equations

- **Example space** – variation within class of examples, in different forms
  Explanatory talk:

"So if we have for example a times b being Equal to zero, this means that … one of the Numbers we are multiplying … is zero. It can either be a is zero or b is zero … "

Ms B (T2) – came in with weak maths knowledge and only limited progress

For example, when she explained how to simplify $\frac{5x-5Y}{10x+10y}$ in contrast to how they had simplified $\frac{10ab^2}{15ab}$ earlier in the lesson she said:

> Ok … so we are looking at the binomial on the numerator and the denominator. Here (pointing to the previous example) we are looking for what's common between because it was a monomial … so can you see that we treat binomials and monomials not the same".

2013 lesson – Factorising expressions
Wider and more structured example set
Explanatory talk ?

Research question

- What relationship, if any, can be claimed between teachers' participation in a *subject matter focused* PD intervention, and *the mathematics they make available to learn* in their teaching?

Subject matter focused PD

Key features of high quality PD (maths ed)

- Subject focused (content …)
- Teachers working collaboratively
- Inquiry type activities
- Linked to professional work

"consensus" in field of maths ed PD? (e.g. Szatjn et al)

RCT studies do not provide support (Hill et al, 2013)

Disentangling relative importance of these features difficult to interpret in many studies

Szatjn et al (in press) – Review PD

Across large number single case research – most with strong subject focus - three themes according to "tools" used (key cases)

- Student thinking
- Video records
- Tasks

Ultimate goal in all is teachers' PCK … (organising principle of the PD) though claims too about learning mathematics

"Connecting to practice … specific tools, pedagogies, implementation of well defined aspects of classroom practice … effective features of PD".

The ‘need’ for specific consideration of SMK

- Research in South and Southern Africa points to important of subject matter focus in and of itself – as organising principle

- E.g.
  - Graven (2002)
  - Adler & Reed (2002)
  - Huillet (2009)

- Mathematical “horizon” … (significant gaps in teachers’ mathematical knowledge) inhibited teachers’ learning from particular forms of PD, despite the above key features.

Studies on teacher learning and change in instructional practice

Goldsmith et al (2013) (review 1985-2008)

Wider variety of representations
More connections
More attention to choice and sequencing of tasks

Criteria for mathematical quality?

Aggregating and averaging of all participating teachers

Studies of diversity in take-up

(1) Munter (2017) – American Journal of Education

Large scale study (200 mid school teachers) relating instructional quality (cognitive demand and accountable talk – IQAMT), MKT and instructional vision (affective factor); multiple observations over time

"On average, MKT (smk and pck) scores were positively related to the current year's quality of instruction, but not growth, while instructional vision scores were positively related to growth in instructional quality. Additionally, …. different patterns of change, depending on teachers' instructional vision and practice at the outset of the study" (p.1).

… in settings in which instructional reform is being promoted, teachers at different initial degrees of appropriation of various pedagogical tools are likely to demonstrate different future patterns of appropriation (p.27).

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(2) Copur-Gencturk & Papakonstantinou (2016) JMTE

Also longitudinal, focused on the effects of professional development on various aspects of teachers' mathematics instruction and thus differences within teachers in relation to th

Shift the discourse (in PD research) from descriptions of averages and aggregates across all participating teachers towards diversity of teacher take-up from PD and disaggregating this in relation to aspects of teaching/instruction.

Changes in/across the teachers AND

In and across teaching

Small scale/ scale

sks,

Teacher learning from PD is thus not only non-linear, and different, but also uneven with respect to different aspects of practice.

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Frameworks, tools for studying maths teaching
Do we need more?

- Several frameworks for considering the quality of maths teaching : e.g. also Ball, Rowland, Baumert
- Don't deal with issues of ambiguity, incoherence and disconnections in teacher talk – or with teaching that is largely 'traditional' and set within large classes
- Homogenise teachers – yet not the same
- Responsive to differences - responsible – and work developmentally

The framework

Mathematical discourse in instruction (MDI):

A socio-cultural framework for describing and studying/working on mathematics teaching

- **Object of learning**
  - **Exemplification**
    - **Examples**
    - **Tasks**
  - **Explanatory Talk**
    - **Naming**
    - **Legitimations**
  - **Learner Participation**

Mediational means

Cultural tools

Mediation towards scientific concepts

Mathematics as network of connected concepts

Building generality and appreciating structure

The intervention – TM course

- ‘20 day professional courses’
- Critical transition
  - Transition Maths 1: Gr 9 – 10
- Focused on mathematics knowledge for teaching - SMK (75%)/pck (25%) - more than half on algebra and functions
- Framework at work here too

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Working with inequalities

1) Comparing numbers: Look at cards 1-5. Is the statement on the card ***true*** or ***false***?

1 $\mathbf{3 < 10}$	2 $\mathbf{-3 < -10}$
3 $\mathbf{10 \leq 10}$	4 $\mathbf{5 > -5000}$
5 $\mathbf{9 - 4 \geq 5}$	6 Make up a tricky numeric example

2) Comparing algebraic expressions: Look at cards 6-10. Is the statement ***always true***, ***sometimes true*** or ***never true***?

7 $\boldsymbol{x^2 > 0}$	8 $\boldsymbol{-x < 0}$
9 $\boldsymbol{(m - 4)^2 > 0}$	10 $\boldsymbol{(p + 2)^2 > 2}$
11 $\boldsymbol{p^2 \leq 0}$	12 Make up a tricky algebraic example

Revisiting school maths (deepening – connections, representations, reasoning) Extending to 'new' maths

Choice and range of examples on cards to focus attention on and through variation

Opportunity for teachers to build full substantiations and justifications

Wits Maths Connect Secondary Project
Mathematics Teaching Framework – Overview

Lesson goal

What do we want learners to know and be able to do by the end of the lesson?

Exemplification

Examples, tasks and representations

- What examples are used?
- What are the associated tasks?
- What representations are used?

Learner participation

Doing maths and talking maths

- What do learners say?
- What do learners write?

Explanatory communication

Word use and justifications

- What is said?
- What is written?
- How is it justified?

Coherence and connections

Are there coherent connections

- between the lesson goal, examples, tasks, explanations and learner participation?

Will learners know and be able to do what you intended? How will you know?

The study

- Participants - 2012 cohort - initially 18, then 10 teachers with full data sets:

- pre and post tests; pre and post lessons

- Constraints - following teachers can't guarantee teaching same grade level …; class changes, many many variables …;

The tests

Pre-test	Post-test
Question 2. Solve for the unknown(s): 2.3 $5(x-5)(y+3)=0$ 2.4 $\frac{4x}{3}-\frac{3x-4}{6}=5-\frac{x-2}{\ldots}$ 2.5 $5-x^2=\ldots$ 2.6 $6x^2=\ldots$ 2.8 $2x-7\ldots$ 2.9 $25^{2x+2}\ldots$	Question 2. Solve for the unknown(s). Give answers correct to 1 decimal digit where appropriate and state any restrictions. 2.1 $(m+1)(m+2)=3$

Pre-test	
Question 8. Is $x^2 \geq x$, for a… sometimes or ne… answer	…onse which …all values …ways …. So the left …hand side. Comment on Peter's response. Identify aspects that are correct and aspects that are not correct. Provide an explanation to convince Peter that his answer is only partially correct.

While 'pre' and 'post' they were not the same test

Post test longer, more challenging questions on more content

Descriptive 'results' - indicative

Data sources – the video recordings

Video recording of a lesson in Feb 2012 (at the start of the course) and then Feb/Mar 2013 (completion in 2012) but when similar content being taught in the schools.

only one lesson per year

Indicative of what teachers presented as their best efforts

Analysing the video transcripts

- Producing the transcript – what was said, what was done; time; clips of all board work.

- Unit of analysis – mathematical episode (math story)
  - Change in content focus – new task; example …
  - Grain size – sub-episodes (purpose driven)

- Each episode analysed for object of learning (goal) exemplifying; explanatory talk; learner participation

- Summative judgment of quality of mathematics as accumulated across/through the lesson

Object of learning				
Exemplification		Explanatory talk		Learner Participation
Examples	Tasks	Naming	Legitimating criteria	
Examples provide opportunities within an event or across events in a lesson for learners to experience variation in terms of *similarity* **(S),** *contrast* **(C),** *simultaneity* **(F)**	Across the lesson le to C sc *Ap ar op pr* e. cl re *U and make multiple connections.* **(C/PS)** e.g. Solve problems in different ways; use multiple representations; pose problems; prove; reason.etc	Within and symbols *Mathematical language used appropriately (Ma)* to refer to signifiers and procedures	Legitimating criteria: convention *General* **(G*)*** equivalent representation, definition, previously established generalization; principles, structures, properties; and these can be partial **(GP)** or 'full' **(GF)**	Learners answer: asks questions (D)

Examples provide opportunities within an episode or across episodes in a lesson for learners to experience variation amidst invariance …. We look for

***similarity* (S),** ***contrast* (C),** ***simultaneity* (F)**

Object of learning				
Exemplification		Explanatory talk		Learner Participation
		ng	Legitimating criteria	
	reason.etc	d nts /or uch as hing, ls me e.g. to of ical ised ely fer to nd s	Legitimating criteria: *Non mathematical (NM) Visual* **(V)** – e.g. cues are iconic or mnemonic *Positional* ***(P)*** – e.g. *a* statement or assertion, typically by the teacher, as if 'fact'. *Everyday* ***(E)*** *Mathematical criteria:* *Local* **(L)** e.g. a specific or single case (real-life or math), established shortcut, or convention *General* **(G*)*** equivalent representation, definition, previously established generalization; principles, structures, properties; and these can be partial **(GP)** or 'full' **(GF)**	Learners answer: *yes/no questions or offer single words* to the teacher's unfinished sentence **Y/N** Learners answer (what/ how) questions in phrases/ sentences **(P/S)** Learners answer why questions; present ideas in discussion; teacher revoices / confirms/ asks questions (D)

Within and across episodes legitimating criteria are:

Non mathematical (NM)

Visual **(V)** – e.g. cues are how things 'look' or mnemonic

Positional ***(P)*** – e.g. assertion, typically by the teacher, as if 'fact'.

Everyday ***(E)***

Mathematical criteria:

Local **(L)** e.g. a specific or single case (real-life or math), established shortcut, or convention

General ***(G)*** equivalent representation, definition, previously established generalization;
principles, structures, properties; and these can be partial **(GP)** or 'full' **(GF)**

Examples	Legitimating criteria
The set of examples provide opportunities in the lesson for learners t experience: **Level 1:** one form of variation i.e. **S**imilarity or **C**ontrast **Level 2:** at least two forms of variation: **S an** S OR **S and C** **Level 3:** simultaneous variation (fusion) of more than one aspect of the object of learning ar connected with similari and contrast within the example set. **(S, C, F)** **Level 0:** simultaneous variation with no attention to similarity and/or contrast	iteria for what counts as thematics that emerge over time a lesson and provide opportunity learning geared towards scientific ncepts. **vel 0:** all Criteria are *Non thematical* ***(NM)*** and so either *ual* **(V)** – e.g. cues are iconic or nemonic; or *sitional* ***(P)*** – e.g. *a* statement or ertion, typically by the teacher, as fact' or *eryday* ***(E)*** **vel 1:** criteria include *Local* **(L)** . a specific or single case (real-life math), established shortcut, or nvention **vel 2:** Criteria extend beyond non thematical and L to include nerality, but this is partial **GP** **vel 3: GF** math legitimation of a ncept or procedure is principled l/or derived/proved

Summative judgment across the lesson in terms of levels 0 - 3

Accumulating examples – towards generality and structure

Building explanation – towards principles of mathematics

Table 1: Summative judgments for interpreting examples and explanatory talk (Adler & Ronda, in Adler & Sfard (2017))

Ms A: T6 2013 Lesson solving quadratic equations

Episode 1	$ax^2 + bx + c = 0$		$(a)(b) = 0$	
Episode 2 (examples) (tasks - done by teacher)	$x^2 = 6x$ $x(x+6) = 0$	$8x^2 = 8$ $8(x^2 - 1) = 0$ $8(x-1)(x+1) = 0$	$(x+1)(x+2) = 0$	$x^2 = 2x + 8$ $x^2 - 2x - 8 = 0$ $(x-4)(x+2) = 0$
Episode 3	Classwork: Solve for x and 6 examples of different quadratic equation forms			

T: So I'm now going to take one example, *x squared is equal to six x* (writing on the board $x^2=6x$) {Ms}. Right, it is *an equation*, it has got *two sides, the left and right hand side* {Ms}. <u>So the first *thing* we need to do is to *put it in standard form*, ok? {NM, Ms}</u> (P) <u>We want all the numbers *to come this side* {NM} and *remain* {NM} with a zero on the right hand side</u> {Ms} (P). So we are going to say, *x squared…if we transpose this six* {Ms} what do we have?

Lrns: *Negative six* {Ms}.

T: *Negative six x equals to*…{Ms}?

Lrns: Zero

T: Then we go back to our *factorisation* by *taking out the highest common factor*. *What is our highest common factor*? {Ma} [proceeds to carry out steps to transform equation into x(x-6)=0]

T: Right, so the only way that this *equation will be equal to zero is when one of the two is zero* {Ma} (GF). If for an example the x akiri zero, right, meaning we are saying *zero multiplied this whole bracket* {NM, Ma}, which gives us zero. *So for a quadratic equation to be equal to zero, one of the products must be zero* {MA} (GP).

T: Right! Let's take a second example [writing $8x^2 = 8$] on the board.

So, here we are going to say, first thing that we need to do is make er the right hand side to be equal to

Lrns: Zero

[The discussion in the second example proceeds in similar fashion]

2013		Examples	Tasks	Naming	Legitimating	L. P.
E1	Defining quadratic equation	NA	NA	Ma	GF, GP	Y/N
E2	Solving quadratic equations	S, S	A->K	Some NM and Ms, mostly Ma	GF	P/S
E3	Solving a variety of quadratic equations	F	A, A->K	Few NM and mostly Ms, Ma	GP, L	P/S
Cum.		L3	L2-> L1	L3	L2	L2

Trs	Exemplification				Explanatory Talk				Learner Participation		Score in Algebra & Function	
	Examples		Tasks		Naming		Legitimating					
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	Pre (%)	Post (%)
T1	L1	L3	L1	L2-L1	L2	L2	L1	L1	L1	L1	20	14
T2	L2	L3	L2-L1	L2-L1	L2	L2	L0	L0	L1	L1	47	39
T3	L2	L1	L1	L1	L2	L2	L0	L0	L1	L1	42	23
T4	L1	L1	L1	L2	L2	L2	L0	L0	L2	L1	40	57
T5	L1	L3	L2-L1	L2-L1	L2	L2	L0	L1	L1	L1	42	66
T6	L1	L3	L1	L2-L1	L2	L3	L0	L2	L2	L2	73	78
T7	L1	L3	L2-L1	L2-L1	L2	L2	L2	L2	L2	L1	48	83
T8	L2	L2	L2-L1	L1	L2	L3	L1	L3	L2	L1	62	89
T9	L2	L3	L2	L2-L1	L2	L2	L0	L3	L3	L3	77	88
T10	L2	L3	L2-L1	L2	L2	L2	L1	L1	L2	L3	77	78

Teachers' take-up

- Targeted group – Gr 9 to 10/11 – revisiting together with 'new' mathematics supported substantial learning of mathematics that provides traction for their teaching (and so responsive to framework for teaching - PCK)

- For some - insufficient traction for deepening and extending mathematics
  - Suggestion of "ceiling" related to initial conditions
  - assumption about what is "known" and needing revisiting not valid

- We didn't need whole study for this ☺ - we have sharpened pre-test, enabling wiser screening at start (and could advise on what might be needed for those we advise 'out')

- Support for differentiated subject focused PD

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Math made available to learn

- Choosing and using examples that provide opportunity for mathematical learning resonates with teachers and evidenced in patterns of more expansive example sets
- Being more conscious and deliberate with some use of mathematical language also resonates
- Task demand and learner participation interact
- Grounding talk in mathematical principles, properties, derived procedures "lags behind" and interacts with learner participation

The power of the framework in our research

- Disaggregates teachers and elements of teaching/ mediational means
- Enables nuanced interpretations of shifts – take-up
- Produces responsible, responsive and developmental description
- Impetus for further more nuanced research as well as "at scale".

THANK YOU!

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DANKIE!

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