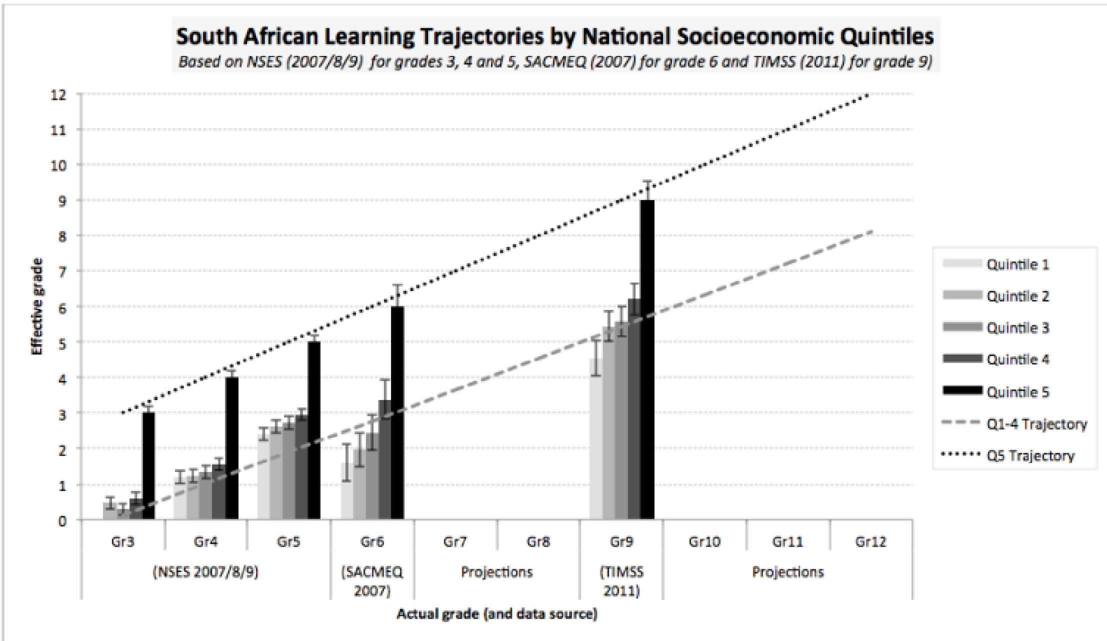
reflective learning

CONCEPTUAL FRAMEWORK

August 2019

FACING A GLOBAL LEARNING CRISIS

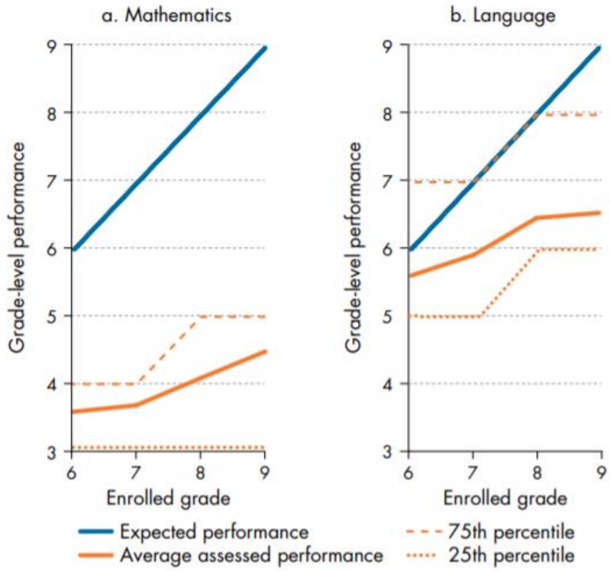
In South Africa, we know that only 10% of learners exit high school with a pass of 50% or more in Mathematics (DBE, 2017). In Physical Sciences this is only 9% of Grade 12 learners. These poor results should not be surprising because when South Africa conducted Annual National Assessments (ANA) at Grade 9 level, only 2% of all learners passed Maths with 50% or more (DBE, 2014). Tracking back further, Spaull & Kotze (2015) analysed numeracy results on the Systemic Evaluation for Grade 3 learners in 2007 and found that in South Africa, only the top 16% of Grade 3 students are achieving at the Grade 3 level and that 60% of learners are already three grades behind by the end of Foundation Phase.



This is not only a South African problem. While Kenya, Tanzania and Uganda have all outperformed South Africa on the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) Mathematics assessments, assessment data collected from 2011 to 2015 reveals the gaps between the expected and actual years of schooling are widening in all three countries. Less than half of Grade 4 children in Kenya, less than a third in Tanzania, and less than a fifth in Uganda can pass Grade 2 tests in numeracy (Uwezo, 2011). In Kenya, a top-performing country in SACMEQ, 11% of Grade 8 learners cannot do Grade 2 Maths (Uwezo, 2012).

In India, national survey evidence reveals that only 27% of Indian children who have completed primary school can perform division, tell time, and handle money, although students should master each of these skills by the end of the second year of school (ASER, 2011). Only 44% of students in Grade 8 can perform this same level of division and 60% of those enrolled in Grade 8 cannot use a ruler to measure a pencil (ASER, 2018). Using several sources of recent data from India, the Center for Global Development's Lant Pritchett examined the number of repeat questions that Grades 4, 6 and 8 students answered correctly. In Maths, achievement only increased from 36% to 53% over the five grade years. This suggests that it would take 32 years of schooling for 90% of all students to correctly answer a question that more than half of all Grade 4 learners already correctly answered (CGD, 2013). Unfortunately, these flat learning trajectories are common. Studies of the impact of education on learning in Bangladesh in the 1990s found that three additional years of schooling had no appreciable impact on learning achievement (CGD, 2013). Interestingly the work of Rothstein (2004, 2010) shows that the reason that there are no significant changes in gaps in Mathematics over time, is because Maths skills are less sensitive than reading skills to the inputs of parents' activities at home.

Assessed grade-level performance of students relative to enrolled grade, New Delhi, India (2015)



Source: WDR 2018 team, using data from Muralidharan, Singh, and Ganimian (2016). Data at http://bit.do/WDR2018-Fig_O-4.

In a cross-national analysis of Maths achievement Bodovski, Byun, Chykina & Chung (2017) made the unsurprising finding that wealthier countries show higher average Maths achievement but, in a study of post-socialist European countries, Ammermüller, Heijke & Wößmann (2005) found that the four highest Mathematics performing countries (Hungary, Czech Republic, Slovakia and Slovenia) also had higher levels of inequality in Maths achievement. PISA Mathematics results have revealed remarkable deficits even in developed industrial countries (Bieber, Niemann & Martens, 2015). With immigrant populations continuing to increase in OECD countries, classrooms are becoming more and more diverse. Globally, an estimated 763 million people live outside the region where they were born (UNESCO, 2018). Immigrant students face a high risk of marginalization in education, resulting in lower levels of learning achievement. While in France, Germany and the United Kingdom, over 80% of 15-year-old students achieve minimum benchmarks in PISA results, immigrants in these countries perform far worse. The proportion of immigrants making it above the minimum benchmark is about 10% less in the United Kingdom, about 20% less in Germany and almost 30% less in France (UNESCO 2014). Indigenous children in high-income countries also face disadvantage, and the gap in learning outcomes with the rest of the population has been persistent. In Australia, around two-thirds of indigenous students achieved the minimum benchmark in Grade 8 between 1994 and 2011, compared with almost 90% of their non-indigenous peers (UNESCO, 2014).

Today, more than 262 million children and youth are out of school. Six out of ten are not acquiring basic literacy and numeracy after several years in school. 750 million adults are illiterate, fueling poverty and marginalization. UNESCO (2014) describe this global learning crisis as costing governments 129 billion U.S. dollars a year, as 10% of global spending on primary education is being lost on poor quality education that is failing to ensure that children learn. Global ambitions for education are captured in Sustainable Development Goal 4 (SDG 4) of the 2030 Agenda which aims to “ensure inclusive and equitable quality education and promote lifelong learning opportunities for all” by 2030 (UNESCO, 2018). In highlighting the importance of implementing strong policies to overcome the global learning crisis, UNESCO identifies the requirement of countries to strengthen their national assessment systems and to ensure that these are used to inform policy. National assessments should be distinct from the public examination systems which are used to promote students between levels of education. National assessments should be a diagnostic tool that can establish whether students achieve the learning standards expected by a particular age or grade, and monitor how this achievement changes over time for subgroups of the population. The results should be used effectively to help education ministries improve education quality and learning outcomes for all (UNESCO,2014).

REFLECTIVE LEARNING CONCEPTUAL FRAMEWORK

Reflective Learning follows a **metacognitive approach** to learning that is informed by the following:

- a **constructivist view** of **personalised learning**;
- visual learning pathways called **conceptual threads** which span the primary school grades up to Grade 9 enabling learners to understand the 'big picture' of Maths and Science and the interconnectedness and interdependence of what they learn in these disciplines;
- diagnostic **assessment *as* learning** with **formative feedback** to drive progress in learning;
- guided self-analysis and self-reflection to enable **metacognitive activation** and **metacognitive skill advancement** for autonomous learning behaviour.

The purpose of the approach is to enable learners, their teachers and parents to **identify learning back-logs**, and with **targeted, personalised catch-up materials** to build understanding from the last place of secure knowledge at a concept level, so as to **fast-track to grade-level learning** in Maths and Science while **developing personal metacognitive skills** that empower independent, self-sustaining successful learning.

A Constructivist View of Personalised Learning

> *"Meaning is not given **to** us in our encounters with the environment,*
> *but it is given **by** us, constructed by each of us in our own way,*
> *according to how our understanding is currently organized".*
> *(Duckworth, 1987, p.102)*

In the epigraph to his 1968 book, well-known educational psychologist, David Ausubel, highlighted the importance of prior learning when he wrote his often-quoted "if I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly". Ausubel acknowledges the importance of the role played by the teacher in the learner's learning. This is elaborated in the social-constructivist ideas of Lev Vygotsky (1978). Vygotsky argued that the capacity to learn from others is fundamental to human intelligence, and with help from those more knowledgeable and more skilled, learners can achieve more than they can on their own. Vygotsky is well known for his concept of the zone of proximal development (ZPD). Unlike Piaget who believed that cognitive development happened through four sequential, age-limited stages, Vygotsky believed that cognitive development could be advanced with the assistance of those who know more. The ZPD is the difference between the developmental level a child can achieve on his or her own and the developmental level he or she could achieve with the input of others. It is the extended learning potential which can be made accessible through 'scaffolding' – the interactions with a teacher or more advanced learner – to co-construct knowledge.

In the classic text *The Psychology of Learning Mathematics* (1971) Richard Skemp describes how mathematical concepts form through a shift from informal thinking (of what already exists in the mind of the learner) to formal thinking (of what is constructed by deduction). Single concepts are embedded in conceptual structures of other concepts called schemas. While concepts are derived from other concepts, they also contribute to the formation of yet other concepts to form a hierarchical organization of our knowledge. According to Skemp these organized networks of ideas power the Mathematics that enables us to understand, predict, and sometimes to control events in the physical world. William Thurston, a Princeton University Maths Professor and Fields medalist describes Mathematics as "a tall subject" referring to the extent that concepts build on previous concepts. He describes this conceptual structure as "like scaffolding with many interconnected supports". He says "once the scaffolding is solidly in place, it is not hard to build it higher, but it is impossible to build a layer before previous layers are in place" (Thurston, 1990, p. 845). Thurston also says "Mathematics is amazingly compressible: you may struggle a long time, step by step, to work through the same process or idea from several approaches. But once you really understand it and have the mental perspective to see it as a whole, there is often a tremendous mental compression. You can file it away, recall it quickly and completely when you need it, and use it as just one step in some other mental process. (p.847)" This mental compression has been further explored by Tall & Barnard (2002) in which they share the neurophysiological evidence of compressed units of mathematical thought discovered by Nobel laureate Gerald Edelman (Edelman & Tononi, 2000). Knowledge compression is also examined by Gray & Tall

(2007) who conclude that mathematical abstraction resulting from the natural mechanism of the biological brain to compress complicated phenomena into thinkable concepts (also called cognitive units), which can be refined in meaning and connected into coherent frameworks, is the key to developing increasingly powerful mathematical thinking.

Visual Learning Pathways – Conceptual Threads

> *"Mathematics is a beautiful subject. Ask mathematicians and others what they love about the subject and they will talk about the amazing connections that thread through the terrain, unifying the different ideas." (Boaler, 2017)*

Conceptual threads engage and support learners by enabling them to see the 'big picture' of learning Mathematics; to be able to identify their own learning gaps within that picture and to understand how their weaknesses are impacting on other related concepts in Maths. It is also a strategy for sharing the responsibility for learning with learners so that they ultimately can understand how they can build their own understanding in Maths. The development of the Reflective Learning conceptual threads has been influenced by Charles' discussion of "Big Ideas" in Maths (2005). Charles defines a Big Idea as "a statement of an idea that is central to the learning of mathematics, one that links numerous mathematical understandings into a coherent whole" (p.10). In developing his Big Ideas, Charles identified what he called "math understandings". He organised his long list of "math understandings" across content strands rather than grade levels. This structure is similar to the Reflective Learning design of conceptual threads with their 81 conceptual landmarks analogous to math understandings.

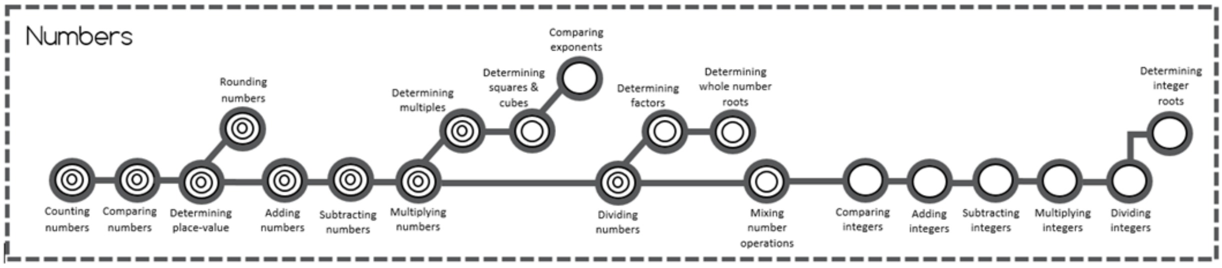
Reflective Learning identifies seven conceptual threads in Mathematics and Science running through the primary school grades preparing learners for high school Mathematics and Science.

Reflective Learning Conceptual Threads MATHEMATICS	**Reflective Learning Conceptual Threads SCIENCE**
• Numbers	• Scientific Inquiry Skills
• Fractions	• Matter & Materials
• Patterns & Algebra	• Chemical Change
• Space & Shape	• Energy
• Measurement	• Force & Motion
• Data Handling	• Electricity & Magnetism
• Problem Solving	• Periodic Phenomena

The term 'conceptual thread' is used in a similar fashion to Prof. Carol Maillet in her development of a 21st Century cross-curricular undergraduate Biology course at Brescia University (2012). A Reflective Learning conceptual thread is a cross-curricular and grade-spanning teaching and learning pathway identified by conceptual knowledge, skills and understandings within a learning area, in the ordered progression in which they typically develop. While the well-known learning trajectories of Doug Clements and Julia Sarama (2004) focus on teaching activities, and the related learning progressions described by Michael Battista focus on the corresponding learning activities, the Reflective Learning conceptual threads are most like what Jere Confrey describes as "conceptual corridors" (2006). Confrey describes learning progressing along a conceptual corridor which is populated by "landmarks" to master and "obstacles" to avoid or overcome.

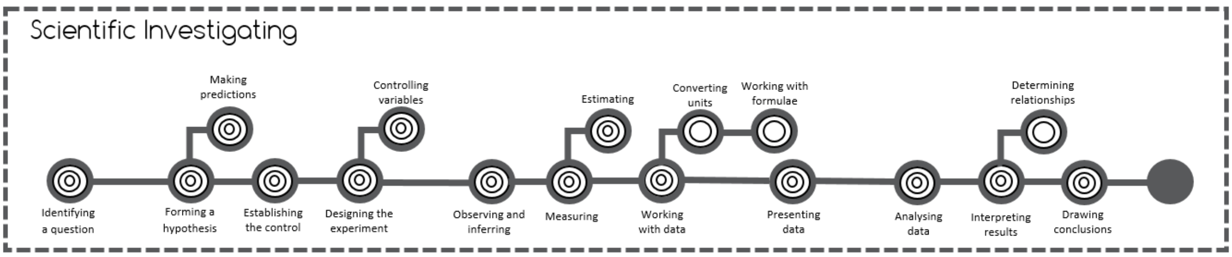
Brown and Campione (1996) also use the word 'corridor' when they refer to "developmental corridors" in their work around the design of innovative learning environments. A developmental corridor is a pathway of learning across school-grades and age. The term developmental corridor suggests that in the early school grades, concepts are introduced and progressively refined, elaborated and extended throughout the progressive grades of school experience.

Along each Reflective Learning conceptual thread are identifiable conceptual landmarks (important concepts to master for learning progress). Conceptual landmarks are benchmarked at Grade 3, Grade 6 and Grade 9 level in Mathematics.
Here is a view of one conceptual thread in Mathematics.



A 'zoomed-in view' of all of the Mathematics conceptual threads shows 25 conceptual landmarks to be mastered in Foundation Phase. Zooming a little further out reveals a further 28 making 53 conceptual landmarks to be mastered in Intermediate Phase and a further zoom out shows another 28 making 81 conceptual landmarks to be mastered by Grade 9 in Senior Phase.

Here is a view of one conceptual thread in Physical Science.



Across all Physical Science conceptual threads there are 72 conceptual landmarks to be mastered by Grade 9 in Senior Phase. Conceptual landmarks are benchmarked at Grade 5, Grade 7 and Grade 9 level in Physical Science. The benchmarking is not unlike the Benchmarks Literacy Maps of the American Association for the Advancement of Science AAAS Project 2061.

Conceptual landmarks along the conceptual threads are the fundamentals of Mathematics and Science underpinning all international Mathematics curricula including the South African Curriculum Assessment Policy Statements (CAPS) although bench-marking is achieved using grade-specific parameters. Achievement on these benchmarks is used diagnostically to measure the extent and depth of learning back-logs and direct a targeted, personalised learning programme at an individual level.

Diagnostic Assessment *as* Learning with Formative Feedback

> *"All teaching really boils down to three key processes: finding out where the learners are in their learning, finding out where they are going, and finding out how to get there."*
>
> *"Assessment is the bridge between teaching and learning."*
> *(Wiliam, 2011 p.45)*

More than thirty years after the term 'formative assessment' was coined, Professors Paul Black and Dylan Wiliam of the University of London, popularized the term with ground-breaking research for the British Educational Research Association (Black & Wiliam, 1998). They redefined formative assessment as "any assessment for which the first priority in its design and practice, is to serve the purpose of promoting learners' learning" (p.1.). The historical idea of assessment was of a summative process and was, what we now refer to as, *assessment **of** learning*. This provided teachers with evidence of learning in order to judge achievement against learning targets, standards or outcomes for public reporting and decision-making about placement and promotion. Formative assessment, also known as *assessment **for** learning*, enables teachers to use information about learners' knowledge, understanding and skills to inform their teaching and to provide feedback to learners about their learning. In 2003, Professor Lorna Earl distinguished between *assessment **for** learning* and *assessment **as** learning* where "assessment ***as*** learning is a subset of assessment ***for*** learning that emphasizes using assessment as a process of developing and supporting metacognition for students" (p.28). In *assessment **as** learning* learners reflect on and actively monitor, analyse and correct their own learning. Learners use feedback to readjust and improve their own learning as they develop and use metacognitive skills. In *assessment **as** learning*, the learner is not only a contributor to the assessment and learning process but is the critical connector between these processes.

As part of the Assessment Reform Group (ARG), Black and Wiliam reported that assessment for learning is the single most powerful tool for raising standards and empowering life-long learning. They also reported that "gains in learning, triggered by formative assessment, are amongst the largest ever reported in educational interventions" (1998a, p.61) and "all students benefit from classroom assessment, however the students showing the largest gains are those who struggle the most" (1998b, p.141). The ARG identified assessment for learning as a research-based principle that is central to classroom practice and a key professional skill for teachers (ARG, 2002). Almost ten years later Popham (2011) claimed that formative assessment well-implemented can double the speed of student learning. Husbands and Pearce (2012) included embedded assessment for learning as one of their "nine strong claims from research" of "what makes great pedagogy". More recently Hofman, Goodwin and Kahl (2015) described how formative assessment (stipulating again that which is well-implemented) can have a multiplier effect on learning by shrinking achievement gaps and increasing educational efficiency.

Through *assessment **as** learning*, learners partner with their teacher to be active participants in understanding and directing their own learning processes. As Lorna Earl explains, "assessment ***as*** learning is the metacognitive process where learners are responsible for their learning and for determining how to move forward … the ultimate goal in assessment as learning is for students to acquire the skills and the habits of mind to be metacognitively aware with increasing independence" (p.52).

The Reflective Learning solution begins with a comprehensive diagnostic assessment.Diagnostic test items are:

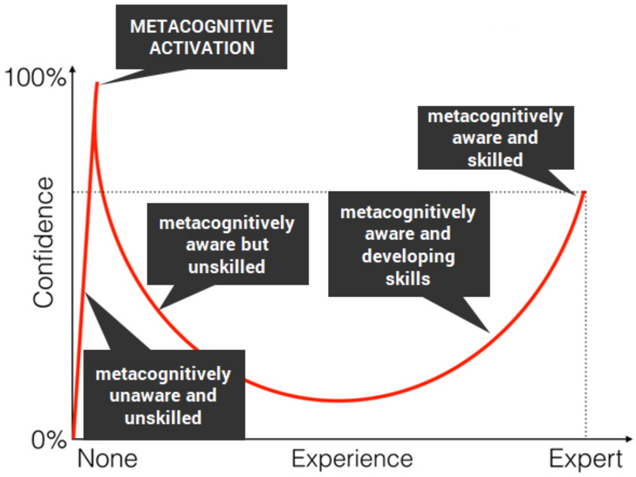
- **purposeful in design** – as in the work of Barton (2018), each item tests a single concept, measures mastery at a specific Grade level that is not necessarily the Grade that the learner is in and informs on misconceptions and alternative understandings.
- **authentically contextualised** – as in the work of Wiggins (1993) items are meaningful to learners in their value, usefulness and importance and support transfer of learning from one educational context to another, for example from formal education to personal real-life and the adult world of work, and from life and work to formal education.
- **formative in nature** – as in the work of Wiliam (2012) each item identifies the grade level at which the learner is functioning, what the learner can do and what the learner cannot do but should be able to do. Feedback focuses on: self-efficacy rather than self-esteem; effort rather than intelligence; the task rather than the individual; what is next rather than what is past and the longer term rather than short term.
- **varied in form** – while some items have closed options such as multiple-choice, some items are open-ended and use the Reflective Learning pop-up keyboard to construct unique responses.
- **simply communicated** - test items are presented in English but read-aloud support assists learners who have difficulties in reading while simultaneously correlating the written and spoken word to develop basic literacy. The language of items is selected to be basic and clear and uses universally recognisable symbols of Mathematics wherever possible. The symbolic presentation of Mathematical items is linear (as in the case of the English words) so as to avoid bias towards specific Mathematical strategies or algorithms. (Refer to Reflective Learning Language Approach)

The next step of the Reflective Learning solution is the provision of a Personalised Reflective Learning Journal to catch up the learner from where they are to where they need to be on each of the conceptual landmarks. The formative *assessment **as** learning* approach is embedded in the Reflective Learning catch-up materials enabling the acquisition of metacognitive language, guiding self-analysis, facilitating discussion and developing the ability to articulate one's own understanding with others to actively construct knowledge. The solution partners learners with their teacher in the common purpose of advancing learners' learning. It activates, develops and advances learners' metacognitive skills by the self-reflective and self-evaluative process that they follow.

Metacognitive Activation & Metacognitive Skill Advancement

> "Not ignorance, but ignorance of ignorance is the death of knowledge".
> *(Alfred North Whitehead, 1929)*

Cognitive activation in Mathematics was highlighted through the Organisation for Economic Cooperation and Development (OECD) Programme for International Student Assessment (PISA) as a teaching phenomenon in which teachers provide opportunities for learners to use thinking strategies when solving Maths problems (Burge, Lenkeit & Sizmur, 2015). When learners begin to question and evaluate their own thinking strategies, a learning phenomenon called metacognitive activation can be observed and recorded (Butchart, 2017).



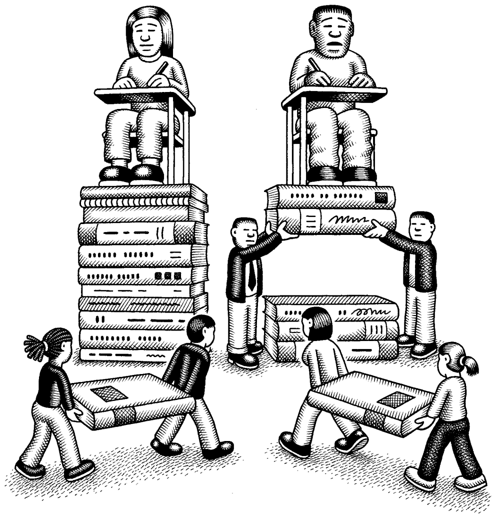
The Potential of Metacognition to Fast-Track Maths Catch-Up Interventions in South Africa -
Butchart, T., & Pournara, C. (2019)

Metacognition can be defined simply as "thinking about thinking" (Flavell, 1971) while metacognitive expertise is knowing what you know, knowing what you don't know, knowing your strengths and weaknesses, understanding how you learn, what strategies and resources you need to learn, and how to access, to choose and to use these. Studies into the implications of a lack of metacognitive expertise by Kruger and Dunning (1999) have coined the Dunning-Kruger effect. Wikipedia puts this as: "a cognitive bias in which low-ability individuals suffer from illusory superiority, mistakenly assessing their ability as much higher than it really is". In *Unskilled and Unaware of It* (1999), Kruger and Dunning found that people tend to hold overly favourable views of their abilities in many social and intellectual domains. This results in an overestimation of their abilities, and these people who are unskilled in these domains suffer a dual burden: not only do they "reach erroneous conclusions and make unfortunate choices, but their incompetence robs them of the metacognitive ability to realise it" (p.1121). In *Why People Fail to Recognize Their Own Incompetence* (2003), Dunning, Johnson, Ehrlinger & Kruger explored this further concluding that people tend to be blissfully unaware of their incompetence and worryingly, if people lack the skills to produce correct answers, they are also suffer an inability to know when their answers, or anyone else's, are right or wrong, so they will never learn what the correct answer is!

Fortunately, the advantages offered by a metacognitive approach in teaching and learning are substantial. For decades now metacognition has been recognised as a most relevant and powerful predictor of learning (Brown, 1978; Flavell, 1976, 1979; Glaser, 1990; Veenman & Elshout, 1999; Wang, Haertel, & Walberg, 1990). In the definitive work on cognitive science presented by Bransford, Brown and Cocking (2000) *How People Learn*, one of the three key findings was the effectiveness of a metacognitive approach to instruction. Increasing metacognitive knowledge and skills contributes to learners feeling more able, and it increases self-efficacy which influences success in learning, motivation and interest in learning (Corno, 1986). In a classroom study, Baird and White (1984) highlight learners' metacognitive skills of self-evaluation as offering the greatest potential for improving learning. There are added bonuses. Paris and Winograd (1990a) conclude "metacognition helps students to develop intellectual curiosity and persistence, to be inventive in their pursuits of knowledge, and to be strategic in their problem-solving behaviour" (p.10). They highlight how metacognition can help learners understand that learning involves overcoming obstacles, confusion and self-doubt. This is particularly valuable for low-achieving learners who gain greater self-efficacy as they learn to understand their frustrations and realise that others share similar feelings.

Metacognitive awareness enables learners to take charge of their own learning (Hacker, 2009). A key element in metacognitive awareness is recognising the limit of one's knowledge or ability and then figuring out how to expand that knowledge or extend the ability. According to Hipkins (2014) teachers should use their expertise to set up conditions where responsibility for learning can be shared. This allows students to assemble their toolkit to go on being learners when teachers are no longer around. According to Cornford (2002), life-long learning, effective learning through one's lifespan, is dependent on knowledge that is centred upon cognitive and metacognitive skills. Most importantly, according to Schraw (1998), metacognitive knowledge, awareness and regulation is teachable. Tanner (2012) describes methods to promote metacognition in the classroom which include: pre-assessments – to encourage students to examine their current thinking; self-reflective questioning – to identify and share their confusions; retrospective post-assessments – to push students to recognise conceptual change; and reflective journals – to provide a forum for students to monitor their own thinking.

THE REFLECTIVE LEARNING SOLUTION



The Reflective Learning solution has been developed over a period that began in late 2011 and has been implemented in South Africa in many different interventions since then. Important learnings have been incorporated into successive intervention designs and these have been documented in learning briefs and research papers.

International Conference Presentations

Butchart, T., Pournara, C. & Barmby, P. (2017). REFLECTIVE LEARNING: USING A DIAGNOSTIC ASSESSMENT AS LEARNING – CONCEPTUAL THREAD APPROACH IN ADDRESSING ACQUIRED LEARNING DEFICITS IN MATHEMATICS IN SOUTH AFRICA. *Proceedings of the 9th International Conference on Education and New Learning Technologies, Barcelona, Spain. 3-5 July, 2017*. https://library.iated.org/publications/EDULEARN17

Butchart, T., & Pournara, C. (2019). THE POTENTIAL OF METACOGNITION TO FAST-TRACK MATHS CATCH-UP INTERVENTIONS IN SOUTH AFRICA. In *43rd Annual Meeting of the International Group for the Psychology of Mathematics Education VOLUME 4*.

Local Conference Presentations

Butchart, T. (2014). ASSESSMENT IS A KEY PROFESSIONAL SKILL FOR TEACHERS - A Case-study of Assessment as Learning in a South African context of Mathematics Teaching and Learning. *SA Basic Education Conference, Johannesburg. 31 March – 1 April, 2014.*

Butchart, T. (2017) REFLECTIVE LEARNING DIAGNOSTICS - Using Formative Assessment to Fix Acquired Learning Deficits in Maths and Science. *EdTech Summit Africa Conference, Cape Town. 28-29 July 2017.*

Butchart, T., Pournara, C. & Barmby, P. (2019). A METACOGNITIVE APPROACH TO CATCHING-UP HIGH SCHOOL LEARNERS' ACQUIRED LEARNING DEFICITS IN MATHEMATICS. *The 27th Annual Conference of the Southern African Association for Research in Mathematics, Science and Technology Education, Durban.*

Butchart, T., Pournara, C. & Barmby, P. (2019). THE POTENTIAL OF METACOGNITIVE ACTIVATION TO IMPROVE LEARNING IN MATHEMATICS. *The 27th Annual Conference of the Southern African Association for Research in Mathematics, Science and Technology Education, Durban.*

Butchart, T., Pournara C. & Barmby, P. (2019) THE POTENTIAL OF METACOGNITIVE ACTIVATION TO CATCH-UP HIGH SCHOOL LEARNERS' ACQUIRED LEARNING DEFICITS in MATHEMATICS AND TO IMPROVE LEARNING. *The Education Fishtank Graduate Conference, Cape Town. 30 March 2019.*

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