Learning about learning: An exploration into the effects of self- and peer-assessment on metacognition in the Mathematics classroom.

Nicola Goemans

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Surname	Goemans
First Name	Nicola
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Abstract

This action research project sought to explore the effects of formative self- and peer-assessment on the metacognition of a class of fifteen Grade 8 students over a period of fourteen weeks. Weekly problem-solving tasks were assessed quantitively and qualitatively by students and their peers, which prompted peer feedback and discourse, as well as self-reflection. An analysis of assessment scores, in conjunction with data obtained from interviews, questionnaires and group discussions, suggests that consistent, guided peer- and self-assessment promotes the development of metacognitive knowledge and skills in students.

Introduction: context and rationale

"If formative assessment is exclusively in the hands of teachers, then it is difficult to see how students can become empowered….."

(Nicol & Macfarlane-Dick, 2006)

A great deal of educational theory makes a strong case for the benefits of formative assessment in the classroom (Black & Wiliam, 1998; Andrade & Cizek, 2010; Wiliam, 2011). The role of the practitioner researcher now becomes one of determining how best to translate those theoretical benefits into tangible learning gains. Formative assessment can take on many forms; peer- and self-assessment are two that provide students the opportunity to learn both collaboratively and introspectively. Going back to Vygotsky, it has been widely acknowledged that learning is enhanced when it occurs through social interactions, while introspection and self-reflection can promote self-regulated learning (Ambrose *et al*, 2010).

The link between formative assessment and metacognition has recently been considered in several studies (Clark, 2012; Isaacson & Fujita, 2006; Tanner; 2012; Siegesmund, 2016). Metacognition is briefly defined as the ability of the learner to be aware of and to analyse her own learning and thinking processes (merriam-webster.com). An improvement in metacognition, together with high levels of motivation and self-concept, can promote self-regulated learning and problem-solving skills in students (Efklides, 2017). The supporting rationale for my research focus is now further developed.

Context: a vignette of a private school in South Africa

National priorities

The general state of education in South Africa is quite appalling: in a league table of education institutions drawn up in 2015 by the OECD, South Africa ranks 75th out of 76 (The Economist, 2017). The severity of the problem is reflected most clearly in the STEM subjects. In the November 2016 Trends in International Mathematics and Science Study (TIMMS), South Africa's ranked position was near the bottom of the standings (The Economist, 2017). In a country where only 37% of children starting school go on to pass the final school-leaving exam (Fourie, 2017), elite private schools take on a role that is double-edged in character. Many of them provide world-class education to students who go on to become economically-active entrepreneurs and professionals. Conversely, only a small minority (3.1% in 2019) of the population can afford this luxury (South Africa's Education Statistics, 2019), and, while government-funded schools continue to provide an inferior learning experience (Fourie, 2017), the prohibitively high cost of many private schools reduces access of countless previously-disadvantaged students to a high-quality education.

Despite these tricky political realities, South African private schools continue play an important role in achieving the current government's policy objective to increase the total number of enrolments in further and higher education institutions from 980 000 in 2017 to 1.6 million in 2030 (Department of Higher Education and Training Annual Report 2017/2018). Secondary national objectives are to increase the number of undergraduate enrolments in science-related degrees, and to reduce the high drop-out rate from Universities and Colleges, which is approximately 40% (CHE, 2013).

<u>School priorities</u>

Many of my students will go on to become the doctors and engineers of our country's future, and I am particularly aware of our school's role in this process. The private, all-boys Catholic school at which I teach currently oversees the education of more than 1500 students from ages 5 to 18. Our school's manifesto makes clear its role in teaching global citizenship and in creating awareness of its responsibility as a school in Southern Africa.

Despite this, while most of my colleagues join parents in emphasising the importance of formal academic results, few are concerned about the value that they might add in preparing their students for life beyond school. And, while our school is known for its consistently excellent examination results, the prevailing pedagogical approach is still teacher-driven 'chalk-and-talk'. We are good at preparing students for success in formal assessments, but are less successful at utilising tools like formative assessment to assist our students in becoming self-reflecting and self-directing. The implementation of formative assessment in our classrooms seemed to hinge on either the personality or level of experience of any particular teacher, and there is little acknowledgement of the potential benefits of this sometimes-abstract interaction that takes place in classrooms every day. While many of our teachers inadvertently include some good formative assessment practices in their daily lessons, I realised that they were often not implemented deliberately or consistently. I also pondered if a more systematic approach could promote a richer and more effective learning experience for the students in my classroom.

Rationale: an educators' quest for change

<u>Personal priorities</u>

As I have gained experience as a teacher, I have found myself intrigued and frustrated by my students' seeming inability to direct their own learning journeys independently or to grapple with problems effectively. My vexation has been further strengthened by a belief that, as a teacher, I should not simply be preparing my students for the next test or examination, but should be developing in them skills that will benefit them at higher-education institutions and during life beyond formal education. Included in this skill set are the abilities to learn independently, to direct one's own learning trajectory, and to solve complex problems. My motivation to encourage independent learning in my students has resulted in a concurrent interest in the theories of self-regulated learning and formative assessment. The results of my Part 2 assignment, which examined the effects of real-time formative assessment and synchronous feedback, confirmed my view that, when carried out intentionally and with purpose, formative assessment can be notably beneficial. This prompted my continued interest in the topic, and my wish to further examine its potential advantages in my classroom.

My limited analysis of the enormous body of research on this, and related topics, has allowed me to develop the following brief synopsis: to prepare my students for higher education and the 21st-Century workplace, I would like to promote academic attainment and increase both self-regulation and problem-solving skills in my classroom; this requires high levels of metacognition in my students (as well as motivation and self-esteem); metacognition can be improved by means of formative assessment and feedback, particularly when peer dialogue, self-assessment, and self-reflection are included in the process (Wiliam, 2011; Clark, 2012). If best practice of formative assessment can positively affect metacognition in my students, then perhaps this could eventually support their development into self-regulated learners who are better able to solve challenging problems. The benefits of this could extend beyond the walls of my own classroom: an improvement in general metacognition and formative assessment skills could have positive effects on their overall academic proficiencies in other subjects.

Consequently, my initial primary research question is: ‘Can intentional and regular formative assessment increase self-regulated learning in my classroom?’ The literature review that follows will examine the themes of self-regulated learning, metacognition, formative assessment and feedback. This process will culminate in the augmentation and refinement of my research questions.

Literature review

Self-regulated learning and metacognition

For many teachers and educational theorists, the evolvement of self-regulated learners is something of a gold standard. Self-regulated learners are proficient learners because, variously, they are able to evaluate the demands and requirements of a task, assess their knowledge and skills, plan and organise their approach to the task, track their progress, and then regulate their strategies if needed (Ambrose *et al*, 2010). Self-regulation is critical to learning (Zimmerman, 2008) and permits students to "have agency over their learning before, during, and after learning experiences" (Siegesmund, 2016, p1).

According to Clark (2012), the self-regulation of cognition and behaviour supports learning because "students acquire the adaptive and autonomous learning characteristics required for an enhanced engagement with the learning process" (p. 205). There is substantial evidence that students who display attributes of self-regulation are generally more effective due to increased levels of resilience, resourcefulness, and self-assuredness (Nicol & Macfarlane-Dick, 2006; Zimmerman & Schunk, 2001). Conversely, less capable students often have "minimal self-regulation strategies" and "depend more on external factors such as the teacher or the task for continued guidance and feedback" (Zimmerman & Schunk, 2004).

Generally, SRL is separated into three distinct phases: planning prior to a task, monitoring of performance progress, and then post-task reflections (Pintrich & Zusho, 2002; Zimmerman, 2000). During the 'planning phase', students "analyse the learning task and set specific goals toward completing the task" (Zumbrunn *et al,* 2011). In the 'monitoring phase', students employ strategies to "make progress on the learning task" and then evaluate the efficacy of those strategies. The final phase necessitates 'reflection on performance'. This self-evaluation phase is crucial, and requires students to assess the efficacy of the strategies that they used during the second phase (Zumbrunn *et al*, 2011). The results of this phase will need to be fed back into the SRL cycle so that future planning can accommodate changes to strategy choices for similar subsequent tasks (Pintrich & Zusho, 2002; Zimmerman, 2000).

The processes with which self-regulated learners engage draw parallels to the three 'phases of work' proposed by Mason *et al* (2010): the 'entry phase' requires students to consider what they already know, what they would like to know or achieve, and what prior knowledge they could introduce to accomplish their objectives; the 'attack phase' occurs once students have a full understanding of the question or problem, and uses various strategies in an attempt to formulate a solution; the review phase includes checking calculations, reflecting on key ideas and implications of conjectures, and extending the results of their solutions to a wider context through generalisation (p. 43).

The link between self-regulated learning and metacognition is affirmed by numerous researchers (Nicol & Macfarlane-Dick, 2006; Siegesmund, 2017; Efklides, 2017; Schraw, 2006). Efklides (2017) states that "motivation and goal-setting are critical components of SRL, and so are the metacognitive monitoring and control of learning process" (p. 1). Similarly, Schraw *et al* claim that metacognition is a central component of self-regulated learning, which they define as "our ability to understand and control our learning environments" (p. 111). They go on to contend that self-regulation necessitates metacognition, motivation, and cognition (Schraw *et al*, 2006). The mastery of metacognitive monitoring and regulation will, together with high levels of affect and cognition, result in improved overall self-regulation, and will ultimately promote the development of self-regulated learners who are able to independently improve their learning experiences and outcomes (Azevedo, 2008; Efklides, 2017; Isaacson & Fujita, 2006).

Since it appears to be so beneficial to learning to become self-regulated, it follows that, as teachers, we should aim to encourage our learners in developing the germane skills, and to create classroom spaces that support this. It thus becomes incumbent on teachers to further understand the phases and characteristics of SRL, and how to promote it during lessons. I would, at this stage, like to acknowledge that, although the promotion of self-regulated learning is my long-term goal as an educator, I have chosen to focus on only one aspect of SRL for this research project: metacognition. Since SRL requires metacognition, cognition, and affect, I felt it was necessary to narrow the focus to only one of those components. The caveat is that metacognition alone is often insufficient for the presentation of self-regulated learning; the other elements also need to be in place for students to regulate their learning for academic attainment (Sperling *et al*, 2012).

What is metacognition?

Various interpretations of metacognition appear in the abundant literature on the subject. The concept of metacognition was first introduced in the 1970s by Flavell (Veenman, 2017). He theorised:

> Metacognition refers to one's knowledge concerning one's own cognitive processes or anything related to them, e.g., the learning-relevant properties of information or data.
>
> (Flavell, 1976)

Metacognition is defined most simply as "thinking about thinking" or "knowing about knowing" (e.g. Metcalfe & Shimamura, 1994). Perkins and Salomon (1989) assert that metacognition enables students to "learn to monitor and direct their own progress". It includes asking such questions as "What am I doing now?", "Is what I am currently doing getting me anywhere?", and "What else could I be doing instead?" Metacognition is a "foundational construct of self-regulated learning" and enables students to "plan and allocate learning resources", to track or monitor their "own knowledge and skill levels", and then assess or "evaluate their learning at different phases throughout the learning process" (Tzohar-Rozen & Kramarski, 2017, p. 2). Flavell argued that if students are able to become more conscious of their learning mechanisms, their awareness of their thought processes can increase, thereby enabling them to gain control, and eventually mastery, of their learning. (Flavell *et al*, 1995).

The basic definition of metacognition can be augmented by describing its constituent elements: knowledge about cognition (metacognitive knowledge), regulation of cognition (metacognitive skills), and metacognitive experience (Cross & Paris, 1998; Shraw & Mosham, 1995; Whitebread *et al*, 1990). Metacognitive knowledge includes knowledge about one's own cognitive ability, and the factors that affect one's learning efficacy, as well as an epistemic awareness of when, how, and why to employ a specific strategy. (Flavell, 1979; Kuhn & Dean, 2004; Cross & Paris, 1988, Schraw *et al*, 2006). Several researchers have, alternately, distinguished between declarative and procedural knowledge to illustrate the differentiated nature of metacognitive knowledge. Kuhn and Dean (2004) characterise declarative knowledge as the "epistemological understanding" of one's academic capabilities (p. 270) and how these are influenced by internal and external elements; this may be considered as a self-appraisal. In contrast, procedural knowledge (also known as conditional knowledge) can be considered the management of cognition, specifically the understanding of which strategies to utilise during a specific task, and when a change of strategy is required. (Schraw *et al*, 2006, Veenman, 2017).

The second component of metacognition, metacognitive skills, includes the monitoring and regulation of one's cognition. Many researchers have asserted that this includes the specific activities of planning, monitoring or regulating, and evaluating or assessing (Shraw & Moshman, 1995; Whitebread *et al*, 1990, Isaacson & Fujita, 2006). Before learning takes place, a student with high levels of metacognition would analyse and understand the context of learning, would set worthwhile goals, and would decide which strategies to employ, given the particular attributes of the learning activity (Azevedo, 2008). During learning, this same student would monitor her progress in meeting her task goals and would assess whether the particular strategies that she has chosen are effective. She would also evaluate her developing understanding of the relevant topic and would make any "necessary adjustments" to her behaviour and strategy choice (Azevedo, 2008, p. 88). When the learning task is complete, the student will, either subconsciously or overtly, evaluate her performance. She will assess whether the stated objectives have been met, and reflect on how application of strategies or learning behaviours could be adjusted for future tasks (Veenman, 2017).

For metacognitively proficient students, the process described above is cyclic in nature (Zimmerman, 2000; Veenman, 2013). The 'learning process' as proposed by Ambrose *et al* (2010) is shown in Figure 1. The metacognitive skills of planning, monitoring and reflection are an integral part of the learning cycle. The ability of the student to assess her task alludes to the role of formative assessment and feedback in completing the learning procedure. These crucial components will be discussed in a later section of this review.

Efklides (2006) has described a third component to metacognition: metacognitive experiences, which she describes as "what the person is aware of and what he or she feels when coming across a task and processing the information related to it" (p. 279). Efklides and Vlachopoulos (2012) state that metacognitive experiences include "metacognitive feeling" (e.g. of satisfaction, confidence) (p. 227) and judgements of effort and learning. Metacognitive experiences function as an "interface between the self and the task" (Aşık & Erktin, 2019, p.86) and represent the on-task experiences of students that emerge before and during cognitive activities. They are a crucial aspect of overall cognition because they "help students control and direct their present and future behaviours by integrating information about the self and experiences" (Aşık & Erktin, 2019, p.87). For example, when a problem-solving task is first presented to students, the emerging metacognitive experiences include "feelings of familiarity, feelings of understanding, and predicted solution correctness" (p.

87), all of which furnish an "intrinsic context" and impact subsequent motivation and effort levels in completing the task.

While metacognitive knowledge is based on previous cognitive experiences, metacognitive regulation and experiences occur during accomplishment of a task and therefore strongly impact 'real-time' decisions and behaviours. Thus, metacognitive experiences play a material role in the overall metacognitive activities of students during activities. Although this component of metacognition is not often considered in the measurement and analysis of students' metacognition, I decided to include it as an element to address in my research in order to gain a richer and more comprehensive understanding of the affective aspects of my students' learning experiences.

A further note on the relationship between self-regulated learning and metacognition

Although I have interpreted metacognition to be subordinate to self-regulated learning, it seems prudent to acknowledge that there is some debate in the literature as to which concept (metacognition or self-regulation) encompasses the other (Gascoine *et al*, 2017), and a firm consensus is still to be reached (Kistner *et al*, 2010; Robson, 2010). Additionally, the definitions of both self-regulation and metacognition (as discussed in the subsequent section) are regarded by some researchers as 'fuzzy' or nebulous (Veenman *et al*, 2006; Veenman, 2007; Kistner *et al*; 2010). Gascoine *et al* (2017) claim note that the "perspective that self-regulation is the overarching concept" is commonly regarded in the literature. Boekaerts (1999) proposed a model with self-regulation as the primary concept, and with metacognitive knowledge and skills being secondary to it. My interpretation is based on this commonly-held view, initially described by Zimmerman (1995), that self-regulation is more than metacognition.

How can metacognition be fostered in the classroom?

Despite the clear benefits to learning of improved metacognition, teachers often do not teach learning strategies or work to enhance metacognitive awareness in their students, even though literature indicates that approaches can be learnt and internalised (Fisher, 2007). Metacognition is an aptitude for self-understanding that all humans, including children, possess. It then follows that there must be techniques and methodologies that we can use to enhance the metacognition of our students. Many studies have been carried out to ascertain what approaches can most effectively improve metacognition in the classroom. These include metacognitive activities (Lin, 2001), exam predictions and electronic learning portfolios (Siegesmund, 2016), extended practice and reflection (Schraw 1998), formative assessment activities and formative feedback (Heritage, 2018; Nicol & Macfarlane-Dick, 2006; Hudesman *et al,* 2013), teacher modelling and prompting (Desoete, 2007), and questioning and discourse (Mevarech & Fridkin, 2006).

For the purposes of my research, I decided to focus on tasks and behaviours that required the active involvement of my students, and which resulted in formative feedback that they could use to improve both metacognition and subsequent academic performance. I thus focused on formative assessment of problem-solving tasks which provided opportunities for and promoted the use of metacognitive knowledge and skills. While teacher involvement and explicit strategy training would be crucial to the process, I wanted the responsibility for its implementation to be largely in the hands of my students. Hence, both peer-assessment, which can prompt communal discourse and collaborative development of metacognition, and self-assessment, which can prompt reflection and introspection, were implemented. The particular approaches to metacognitive enhancement that I will briefly discuss in the next few paragraphs all support collaborative talk or the generation of feedback, which allows students to retrospectively examine the outcomes of their behaviours and strategy applications, and to consider how to effect changes for future tasks. This mulling, analysis, and reflection of self and task should promote the development of metacognitive skills (Clark, 2012).

Teachers can utilise modelling and prompting during explicit instruction in order to train their students in the application of metacognitive strategies while grappling with challenging tasks. These strategies may include "error detection, the allocation of effort and attention, elaborating, self-questioning, self-explanation, constructing visual representations, activating prior knowledge, rereading difficult text sections, and going back to revise" (Lin, 2001, p.25). Specific metacognitive and problem-solving strategies, such as skimming, slowing down, diagrams, and activating prior knowledge, can also be taught by means of, for example, a Strategy Evaluation Matrix (SEM), as suggested by Schraw (1998). This modelling and prompting should, ideally, give rise to teacher-student and student-student dialogue, which can facilitate collaborative development of metacognition (Desoete, 2007).

In the classroom, dialogue is important because it is the "primary means for developing intelligence in the human species" (Fisher, 2007). In school, teachers are the primary facilitators of children's cognitive and metacognitive awareness. Much of the instruction in both cognition and metacognition takes place as classroom talk, and the forms of learning conversations that stimulate thinking are those that encourage verbal interaction and can be described as 'dialogic' (Alexander, 2006). This links back to the socio-constructivist approach to learning (Vygotsky, 1978) that "stresses the situatedness of every learning activity and points to the close interactions between cognitive, conative and affective factors in students' learning and problem solving" (Op 't Eynde *et al*, 2006).

Thus, metacognitive knowledge and skills of students can be encouraged through “a kind of reflective discourse” which actively involves students (Desoete, 2007). Often, teachers discuss and carefully model their cognitive processes (how to perform a task) but omit to model their metacognitive processes (how they think about, and monitor their performance of the task while working on it) (Shraw, 1998). But many metacognitive tools and strategies can be explicitly modelled and then encouraged through dialogue and verbal prompting. For example, children can be encouraged to slow down during difficult tasks, or to activate prior knowledge and make use of diagrams during problem-solving (Desoete, Roeyers & De Clercq, 2003). Crucially, all teachers can kick-start students’ metacognitive thinking by explicitly sharing and then discussing the learning goals and objectives of each lesson (Eilam, 2017). Dialogue can also form part of what Desoete (2007) calls a “powerful teaching environment” which fosters self-reflection and improvement, and which assist students in attributing their successes to the “use of adequate strategies and self-regulation” (p. 717).

Dialogic teaching and modelling can be extended to include classroom discourse amongst learners and their peers. When teachers include conversations about metacognitive knowledge and skills in the everyday discourse of their classrooms, they help their students foster appropriate language to aid them in discussions about cognition and strategies amongst themselves (Pintrich, 2002). In a small-scale study on 9- and 10-year olds, Smith and Mancy (2018) found that collaboration can increase and improve the transactive metacognitive talk amongst students. Numerous other researchers also advocate the use of collaborative learning in promoting the synthesis of metacognitive skills (Cross & Paris, 1988; Hennessey, 1999; Martinez, 2006). Kramarski and Mevarech (2003), claim that students who participated in group learning activities articulated their mathematical thoughts and ideas more clearly than those who worked alone, and Schraw and Moshman (1995) noted that “peer interaction can encourage the construction and refinement of metacognitive theories, which are frameworks for integrating cognitive knowledge and cognitive regulation" (Lai, 2011, p. 25). Kuhn and Dean (2004) assert that social structures that promote discourse allow students to internalise metacognitive skills through the provision of "explanations and elaborations", and that this has resulted in improved learning outcomes. Even when tasks are carried out individually, formative peer-assessment and peer-generated feedback can encourage peer discussions and collaborative discourse. Pintrich (2002) supports these assertions by arguing that "making the discussion of metacognitive knowledge part of the everyday discourse of the classroom helps foster a language for students to talk about their own cognition and learning". This common vernacular can increase students' awareness of "their own metacognitive knowledge as well as their own strategies for learning and thinking", and can enable classroom discourse that makes cognition "more explicit and less opaque to students" (p. 223).

While it is clear that the development and enhancement of metacognition is supported by student interactions with teachers and peers, there will also come a time when individual work and task-completion is required. Through reflection and self-evaluation, students can develop the tools necessary for the application of metacognitive thinking during challenging tasks. Pintrich (2002) states that with practice and "development, students become more aware of their own thinking as well as more knowledgeable about cognition in general" (p.220). Boud *et al* (1985) developed a model, 'Reflections in Learning' which "involves intellectual and affective activities in which individuals engage to explore their experiences in order to lead to new understandings and appreciations" (p. 19). This conceptual framework posits that the individual student's reflections (written or verbal) that occur after academic experiences (such as assignments, or in-class activities) can result in improved metacognitive self-knowledge (e.g. of strengths, weaknesses, preferred learning styles).

Reflection after tasks speaks specifically to the third theoretical phase of SRL: self-reflection. It encompasses both reflection of self, as well as a more objective comparison of the information that results from self-monitoring while on-task to a pre-specified, standard learning goal (e.g. How far am I from meeting the learning goal? What are the gaps? What should I do to close those gaps?) (Isaacson & Fujita, 2006). According to Menz and Xin (2016), reflection is the process of "internally examining and pondering – carefully and critically – an experience and its meaning to the self" (p. 158). Their study into the use of reflective writing demonstrates that teachers can intentionally target and affect metacognitive knowledge by providing them with opportunities to write reflectively (Menz & Xin, 2016). Keestra (2017) proposes that "philosophical reflection" is a natural assistant to metacognition which requires "individuals to not take their own thinking and thoughts for granted but to critically scrutinise them" (p. 141). Schraw (1998) claims that: "Extended practice and reflection play crucial roles in the construction of metacognitive knowledge and regulatory skills" (p. 118). Further, he asserts that studies show that reflection, "both as a solitary and group endeavour" promote metacognitive awareness in students. Self-assessment activities can promote reflection by students (Andrade, 2010).

The particular context in which metacognition is developed is also important, since knowledge and skills can be general when concerned only with the self-as-learner, or domain-specific when applied to a specific subject, such as mathematics (Lin, 2001). The advancement of skills relevant to mathematics is supported by problem-solving tasks (Lin, 2001; Coles, 2013; Desoete *et al*, 2013; Smith & Mancy, 2018). This notion will be further explored in the next subsection.

Metacognition and problem-solving in the mathematics classroom

Mathematical problem solving a valuable aspects of mathematics education, and one that most often presents extraordinary challenges to school-going children (Tzohar-Rozen & Kramarski, 2017). The challenges experienced by students may prevent them from understanding mathematical texts, recognising several possible alternative approaches for solving problems, and feeling confident when calculating and verifying solutions (Desoete *et al*, 2003; Schoenfeld, 1992).

Problem-solving abilities in mathematics education are seen as a “complicated interplay between cognition and metacognition” (Panaoura *et al*, 2001). Various researchers have claimed that metacognitive skills and processes are necessary for the successful development of a solution to a complex mathematical problem (Carr & Biddlecomb, 1998; Tzohar-Rozen & Kramarski, 2017). Research on problem solving suggests that simply learning about the existence of procedures and problem-solving techniques is not sufficient, but that students must be taught when to apply such strategies (McLoughlin & Hollingworth, 2001). An effective employment of cognitive techniques is possible only when metacognitive skills are in place (Özsoy & Ataman, 2009).

Metacognitively proficient students are often able to make use of the higher-order processes that assist in problem-solving such as, checking for accuracy, breaking a complex problem down into simpler steps, questioning their objectives and the strategies that they have selected, modifying their selected approaches if necessary, and assessing their solutions for sense within a given context (Panaoura *et al*; 2001). Schoenfeld (1992) describes simple strategies that students can be taught to help them gauge their attainment during mathematical tasks, such as pausing regularly during problem solving to ask themselves questions such as “What am I doing right now?”, or to slow down and read sentences carefully. Desoete’s study (2007) determined that “metacognitive training improved pupil performance in mathematical problem solving and was found to have a sustained effect" (p.718).

There are several specific metacognitive strategies that mathematics educators can teach their students to apply during problem-solving activities (du Toit & Kotze, 2009). A planning strategy will encourage learners to become aware of the time restrictions, goals and 'ground rules' of a particular learning activity, and to consider which strategies, rules and steps could be used (du Toit & Kotze, 2009). A questioning strategy will prompt learners to ask themselves what they know and what they do not know at the start of a task (Blakey and Spence, 1990), and to identify any given information and assumptions that must be made (Ratner, 1991). An articulation strategy can help learners identify their thinking processes, and may aid them in identifying gaps in their knowledge, or misconceptions. Muijs and Reynolds (2005) use the term 'articulation' to "describe learners' expression of their own ideas" and "recommend that learners discuss complex tasks and present their ideas to fellow learners" (p.64).

Mason *et al* (2010) argue that, to think mathematically, students need to develop an 'internal monitor' and become their 'own questioners'. The role of the internal monitor is to increase awareness of the processes, activities, and aspects of thinking that take place while work is being done. They emphasise the distinction between "being involved in thinking", which is akin to 'cognition', and "monitoring the involvement", which is akin to 'metacognition' (p. 107), and underline "the importance of reflection in contributing to that awareness" (p. 107). Becoming your own questioner requires that you develop skills in noticing your own work, and the questions that arise as a result. These questions may be related to your own knowledge and understanding, or they may be concerned with the task itself (Mason *et al,* 2010). Both the internal monitoring and the questioning skills are linked to metacognitive behaviours which also require understanding, observation, and regulation of task and self.

The strong link between metacognition and problem-solving has impacted my research in two ways. Firstly, I have been motivated to increase my students' metacognition in the hope that this will then lead to improvements in their problem-solving abilities, which is vital for both academic attainment in a variety of subjects at school, and general life-long skills development. Secondly, I designed my intervention primarily around the formative assessment of problem-solving and error-detection tasks because they provided the ideal frameworks on which to encourage the development of my students' metacognitive knowledge, regulation, and experiences. It is important to now consider the effects of formative assessment and feedback on metacognition.

Promoting metacognition using a formative approach

A recurring theme in the theories of how to promote metacognition in the classroom is that of using reflection and feedback resulting from tasks to guide the learning journey. This feedback can be generated individually, or through discussions with others, and can be verbal or written. The resulting data can allow students to select alternative strategies, consider the accuracy of their methods, and identify areas of strength and weakness. This feedback is considered formative because it informs students about 'where they are' in their learning journey or problem-solving activity, and 'what to do' to reduce the disparity between their current position and their final goalpost.

Formative feedback is often the result of a formative assessment activity which is used not to 'measure learning' but as a process during which students and teachers can gain a greater understanding of what learning approaches may need to be modified going forward to improve the learning experiences, understanding, and academic achievement of students. An ‘evolutionary’ perspective proposes that “for individuals to be successful, they require a formative environment: one in which they first have access to information, second consciously select information and finally use the information strategically in order to regulate learning and achieve desired performance outcomes” (Clark, 2012, p. 226). The concept of formative assessment, and how its resulting feedback could be used to promote metacognition (and, ultimately, self-regulated learning), is explored further in the next subsection.

Formative assessment and feedback

What is formative assessment?

Literature indicates a strong link between self-regulated learning, metacognition, and formative assessment (in particular, the formative feedback that it produces) (Clark, 2012; Nicol & Macfarlane-Dick, 2006). Often called ‘assessment for learning’ (Wiliam, 2011), the term ‘formative assessment’ was initially used by Michael Scriven to describe the role that evaluation could play in the continuing improvement of learning and teaching (Scriven, 1967; Wiliam, 2011). Andrade and Cizec (2010) assert that it is “the collection of information about student learning” for the purposes of “identifying students’ strengths and weaknesses”, assisting educators in the planning and improvement of their lessons, aiding students “in guiding their own learning, revising their work, and gaining self-assessment skills”, and encouraging “greater autonomy and responsibility for learning amongst students” (p. 4). Clark (2012) asserts that ‘Assessment for Learning’ (AfL) is “the collaborative and individual reflection on evidence of learning. It is a process where pupils and staff set learning goals, share learning intentions and success criteria, and evaluate their learning through dialogue and self and peer assessment” (p. 208).

These various definitions point to the notion that formative assessment is a process, not a product. When the evaluation of some product, activity, task, or performance occurs formatively, it will include comparison of student output with known, explicit criteria; it will actively involve students; it will generate feedback that can be used by both students and teacher to modify subsequent thoughts, behaviours and feelings. It should not be in the hands of the teacher only. In fact, Wiliam (2011) advocates that some key elements be put in place in the classroom in order to improve learning, including "the active involvement of students in their own learning, the adjustment of teaching to take into account the results of assessment, and the recognition of the profound influence assessment has on the motivation and self-esteem of students" (p 39). He and his colleagues (Leahy, Lyon, Thompson & Wiliam, 2005) propose the following five key strategies of formative assessment:

1. Clarifying, sharing, and understanding learning intentions and criteria for success.
2. Engineering effective classroom discussions, activities, and learning tasks that elicit evidence of learning.
3. Providing feedback that moves learning forward.
4. Activating learners as instructional resources for one another.
5. Activating learners as owners of their own learning

(Wiliam, 2011, p 46)

These strategies promote the creation of critical feedback loops: diagnostic-focused activities provide teachers and learners with specific data as to what has been understood, misunderstood, or misconceived, and appropriate actions can be taken by relevant stakeholders to re-direct, reinforce and improve learning going forward (Karuza, 2014). A similar model is provided by Nicol and Macfarlane-Dick (2006). Their model aims focuses on achieving "good feedback practice" and self-regulated learning, by means of facilitating the "development of self-assessment (reflection) in learning", encouraging "teacher and peer dialogue around learning", and delivering "high-quality information to students about their learning" (p 205).

When students are "activated as instructional resources for one another", they are involved in the process of 'peer assessment', and, similarly, when students are activated as "owners of their own learning", they become intrinsically involved in the formative assessment of themselves, or "self-assessment". In Andrade and Cizek's 2010 *Handbook of Formative Assessment*, it is argued that, through self-assessment, students can become the "definitive source of formative assessment" (p.90), and that "peer assessment also promotes reflection" (p.62). Peer- and self-assessment, as productive elements of formative assessment and effective generators of feedback which may promote metacognition, are discussed in subsequent sections.

How does formative assessment relate to metacognition?

Through formative assessment, students become active participants in the learning process and co-owners of assessment (Andrade & Cizec, 2010). Tanner (2012) successfully utilised formative activities to improve the metacognition of her students. These included pre-assessments, which encouraged students to "examine their current thinking" (p.116) prior to learning, and "retrospective assessments", which pushed students to "recognize conceptual change" (p.116) after learning had taken place. Further, students were required to keep reflective journals about their metacognitive thinking and learning strategies, which, if updated regularly, Tanner claims, allows students to "bring a more metacognitive stance to their every-day coursework" (p.117).

Heritage (2018) posits that metacognition and self-regulated learning are supported through a "process of co-regulation between teacher and student in the context of AfL" (p. 51). She confirms the connection with Vygotsky's "concept of socially mediated learning" and the general neo-Vygotskian view that learning is a "culturally based communicative process, through which knowledge is shared and constructed" (p. 51). The primary focus of AfL is the development of the agency of students in their own learning experiences (Black & Wiliam, 1998). Thus, a core objective of formative assessment is to assist students in the development of 'learning to learn' skills "so that they are able to continue learning for themselves beyond school" (Heritage, 2018, p. 52). Clark (2012) agrees when he argues that feedback from formative assessment is the underpinning construct of metacognition and self-regulated learning, and he locates it at the centre of his model of the theory of formative assessment (TFA).

One of the objectives of formative assessment and its associated feedback is the complete engagement of the student with metacognitive activities such as goal-setting and planning, monitoring and reflection, which give learners the "power to oversee and steer one's own learning so that one can become a more committed, responsible and effective learner" (Black & Jones, 2008, p. 8). Nicol and Macfarlane-Dick suggest that "formative assessment and feedback should be used to empower students as self-regulated learners" and Butler & Winne (1995) emphasise the role of feedback in regulating learning advancement. This feedback could be internally-generated, as a result of self-monitoring and self-assessment, or externally-generated, as a result of peer- or teacher-assessment in response to a learning activity (Sadler, 1989; Clark, 2012). The feedback and evidence that is gathered by both teachers and students during formative assessment activities is fundamentally for the purposes of student reflection: they can utilise the information for self-management and self-control (Zimmerman, 2000). The pragmatic aspects of peer- and self-assessment will now be presented.

Peer- and self-assessment

As stated, students are more likely to achieve their learning goals if they understand those goals and then evaluate what needs to be done to achieve them. Self-assessment – the ability to assess one's academic performance against a set of defined goals – is therefore critical if learning is to take place (Sadler, 1989). When students execute self-assessment processes in the classroom, they develop a broad, layered view of their work that aids them in managing and regulating it for their own attainment (Black *et al.*, 2003). As a praxis, peer-assessment is a valuable complement to self-assessment. Berry (2008) goes so far as to suggest that self-assessment and peer-assessment are inextricably linked and should, necessarily, not be discussed as disparate processes. Indeed, Boud (2007) warns against allowing self-assessment practice to become an "isolated or individualistic activity", but suggests that "it commonly involves peers, makes use of teachers and other practitioners" (p. 122).

Self- and peer-assessment, as elements of AfL, require students to reflect on their own, and their fellow students', learning and to ascertain what could be done to effect improvements (McDonald & Boud, 2003). Students can, through these kinds of assessments, cultivate the skills required to track and measure their own learning, hone their ability to sensibly judge work, and make appropriate decisions about subsequent efforts (Berry, 2005). If implemented well, self-assessment can elevate students' self-esteem, and teachers need to assist them in developing the capacity to take charge of their own learning through regular, guided self- and peer-assessment activities (Ross, 2006).

Strijbos and Sluijsmans (2010) define peer-assessment as "an educational arrangement where students judge their peers' performance quantitively and / or qualitatively and which stimulates students to reflect, discuss and collaborate" (p.265). Falchikov (2005) argues that in peer-assessment, "students use criteria and apply standards to the work of their peers in order to judge their work" (p. 27). Its importance is highlighted in various educational studies. Slavin (1997) considers peer assessment to be one of the greatest educational successes and, pedagogically, peer-assessment can increase the learning of students through a "sense of ownership and responsibility, motivation and reflection of the students' own learning" (Saito & Fujita, 2009, p. 151). When peer-assessment is formative, and used for learning, it takes place in open and supportive community, and is both a cause and result of social reflective discourse (Clark, 2012). It is the "variability" in students' experience which allows them to scaffold each other's understandings and co-construct shared meanings.

Formative peer assessment draws on many socio-constructivist aspects of learning mathematics; that the "extension and establishment of links between existing and new knowledge, as well as remembering and understanding" are enhanced when students "regularly explain their work to each other" (van der Walt *et al*, 2008). Thus, formative peer assessment includes not only the evaluation of others' work against criteria, but the subsequent discourse around such judgements, how they were made, and what they imply for future learning for all students involved in the assessment process. Students are therefore required to provide appropriate feedback to each other as an integral component of peer-assessment. The quality of peer assessment and feedback can be improved if teachers model good feedback practices before students engage in the assessment activities themselves, and continue to facilitate the per-to-peer interactions if necessary (Falchikov, 2007).

Gielen *et al* (2010) provide some valuable guidelines for effective peer feedback. Their study confirmed that peer-assessment is more effective when academic parity is used to inform the creation of student groups. In addition, they suggest that constructive feedback should include comments related to the assessment criteria, an explanation of their judgement, suggestions for improvement, both positive and negative comments (unless no negative comment is possible), and some thought-provoking questions (p. 308). The feedback should lead to discourse, and should not cause unnecessary distress.

Self-assessment, at face value, involves the act of a student assessing her own work, either quantitively or qualitatively. When this assessment takes place formatively and is used to generate feedback for the student which can enhance her future learning experiences and improve her metacognitive skills, it becomes a very powerful tool. Although there are a number of definitions of the term self-assessment, many of them are quite general. Montgomery provides the following: self-assessment is "an appraisal by a student of his or her own work or learning process" (p.5). Blatchford asserts that self-assessment is a component of student self-concept, and involves "judgements of one's own attainment in relation to other children" (p. 2). Most interpretations of self-assessment do not view it as a normative judgement, but emphasise its formative value in monitoring the progress of one's own learning and implementing remedial measures to improve learning (Andrade, 2010). Rolheiser and Ross (2000) view self-assessment as "students judging the quality of their work, based on evidence and explicit criteria for the purpose of doing better work in the future" (p. 3).

According to Siegesmund (2017), self-assessment is a "reflective process where students use criteria to evaluate their performance and determine how to improve" (p. 2). It is important to note that self-assessment, which is meant to be formative, is quite different from self-evaluation, which is the process of assigning a numerical value or grade to a piece of work (Andrade, 2010). Self-assessment is shown to be important for both current and life-long learning, and that it "increases motivation, empowers students to take responsibility for their learning, and leads to increases in student learning" (Siegesmund, p. 2). Both Tanner (2012) and Siegesmund (2016) argue that the process of self-assessment increases metacognition, and that in executing it, students may ultimately become more accomplished at gauging their progress towards meeting their learning goals.

Andrade and Valtcheva (2009) confirm that "self-assessment is a key element of formative assessment because it involves students in thinking about the quality of their own work, rather than relying on their teacher as the sole source of evaluative judgements" (p. 13). Andrade (2010) asserts that for effective self-assessment to occur, the following need to be in place:

- Awareness of the value of self-assessment,
- Access to clear criteria on which to base the assessment,
- A specific task or performance to assess,
- Models of self-assessment,
- Practice,
- Opportunities to revise and improve the task or performance. (p. 93)

These criteria are further supported in a later study by Andrade and Valtcheva (2009): their findings confirm that, as they gained experience, students displayed more positive attitudes towards self-assessment, and that students believed that they could self-assess successfully when they had a clear idea of what was expected of them. Further, they ascertained that self-assessment should involve the checking of progress towards learning goals, followed by opportunities to revise and reflect. They found that, on the whole, students came to believe that there were considerable benefits of self-assessment, such as the ability to identify key elements of a task, an increased efficacy in recognising the strengths and shortcomings of their work, greater motivation and engagement, and reduced anxiety (p.16). Ross (2006) recommends that teachers "define the criteria by which students assess their work", and assist students in using self-assessment data to improve their subsequent academic performances. Andrade and Valtcheva (2009) add to this by suggesting that the following conditions are met when self-assessment activities take place (p.17):

- Provide sufficient time for revision after self-assessment, and
- Do not turn self-assessment into self-evaluation by counting it towards a grade.

Self-assessment can be further expanded into the concept of self-reflection. According to McMillan and Hearn (2008), "reflection is a critical part of the self-evaluation process" (p. 46). Self-reflection can encourage students to consider what they know and have learnt, as well as what areas of learning they find challenging, and what they still need to work on. Students can benefit from explaining their work and ideas to themselves and to others through reflective activities such as checklists, self-reflection journals, or written correspondence with peers (McMillan and Hearn, 2008). Self-reflection can also assist students in the development of their self-concept (Lin, 2001). Research highlights the importance of "knowing the learner-as-self in promoting metacognition" (Lin, 2001, p. 27), and acknowledges the value of understanding the role of the self-as-learner in relation to certain social contexts (Bandura, 1986). The evolution of a student's self-concept is viewed by some as a "series of reciprocal interactions between personal variables (e.g. behaviour, thinking, decision-making, affect, confidence, emotion) and the social environment" (Lin, 2001, p. 27). Self-concept is strongly linked to the specific concept of Metacognitive Experience which was discussed earlier in the review. Efklides and Tsiora (2002) researched this link and found that Metacognitive Experiences such as Feelings of Difficulty (FOD), Estimate of Effort exerted (EOE) and Feelings of Confidence (FOC) are influenced by students' views of their mathematical ability based on previous grades and experiences and by their mathematical self-concept, and will influence subsequent task-specific self-concept. In the absence of careful and capable self-reflection, or effective external feedback, the effects of a student's performance on a task is influenced and mediated by Metacognitive Experiences (p. 227)

Linking the literature to classroom practice and my research

Initially, my focus was on the effects of only self-reflection on metacognition and academic attainment, but, over time, my review of the literature impressed upon me the importance of maintaining a collaborative, social approach in my practice. I thus modified my objectives to include both self- and peer-assessment activities. The self-assessment endeavours of my students would encourage them to become introspective and reflective about their learning efforts, while the peer-assessment tasks would allow them to develop their metacognitive thinking and skills socially, thereby providing them with opportunities to bolster each other's ideas and to collaboratively construct understanding of their own thinking processes. While self-assessment often relies on only written self-questioning, the verbal articulation required by peer-assessment supports a deeper and more coherent understanding of one's learning strengths, weaknesses, and skills. For this research undertaking, self-assessment was taken to be the comparison of one's work to a defined set of criteria, while self-reflection was taken to be the guided self-questioning that took place before, during, and after the assessment tasks.

Overall, as a result of my review of the literature, I designed my study to include:

- Training of my students in in the application of metacognitive strategies during mathematics problem solving.
- Problem-solving tasks that required metacognitive knowledge and skills (both general and domain-specific).
- Peer-assessment activities with sufficient time and support for feedback and ensuing collaborative conversations.
- Self-assessment activities that required self-reflection and revision of work.
- Plenty of time and opportunities for my students to practise these processes.

Methodology

My review of the literature enabled me to more carefully consider the objectives of my research, and how to measure the success of my classroom intervention. It became clear that I wanted to focus on the specific link between the outcomes of formative peer- and self-assessment activities, and the levels of metacognition of my students. To this end, my research questions are refined and expanded as follows.

1. What are the existing formative assessment practices within my school?
2. Does the implementation of self-assessment and peer-assessment practices have a positive effect on the metacognitive knowledge and skills of students?
3. Does the implementation of self-assessment and peer-assessment practices impact the metacognitive experience of students?
4. Is it possible to teach young students to evaluate their own learning metacognitively both during and after a task or learning activity has taken place?
5. Do the self-reflection, peer- and self-assessment skills of a group of students improve over time, with guidance, practice and effort?

My research questions and methodologies are based on the interpretivist paradigm which "challenges the idea that social researchers can view things from an objective position" (Denscombe, 2014, p.2). It views social reality as a construct which is based on people's thoughts and actions. This paradigm is further supported by Cohen *et al*'s 'discovery perspective' (2010) which asserts that the aim of the researcher is to "gain understanding of how individuals make sense of their worlds" (p. 43). Therefore, the role of the researcher is to interpret social phenomena, whist being conscious of the fact that her views and thinking are unavoidably shaped by her own experiences and identities. Consequently, the overarching aim of my research is to "develop insights into people's beliefs and lived experiences" (Denscombe, 2014, p.2) so that I can become overtly aware of how my students' learning and understanding can be enhanced, and check the effects of my practice.

Research parameters and proposed timeline

My research sample was a class of fifteen Grade 8 students (thirteen- and fourteen-year olds). They are a mixed-ability group of boys, with year-to-date mathematics results ranging from 49% to 93%. My research took place over a fourteen-week period between March and July 2019. The first two weeks were 'exploratory training weeks' during which I explained the purpose of the intervention and the value of metacognition in their learning. My students and I also utilised this time to practise defining learning objectives, implementing peer- and self-assessment activities, generating and delivering appropriate feedback, and employing key metacognitive strategies during problem-solving. Furthermore, this time provided an opportunity to investigate the existing formative assessment practices at my school. This was done through a semi-structured group discussion at a staff development session.

Initially, I aimed to carry out a practitioner research project. However, when I was compelled to adjust and improve my data intervention and data collection methods, my project developed into an action research study with three cycles. Each cycle comprised four weeks in total: three weeks for intervention activities and data collection, and one week for reflection and modifications to intervention and data collection methodologies. The data from each research cycle was examined and used to make improvements to the subsequent intervention activities. The timeline is summarised:

Research phase	Objective	Time allocated and participants
Exploration and training	Instruct students in using metacognitive strategies while solving mathematics problems. Investigate the existing formative assessment practices of my colleagues by means of a group discussion at a staff development session. Collect pre-intervention data using metacognitive questionnaires.	Two weeks Grade 8 students School-wide colleagues
Cycles 1 - 3	Refine intervention. Collect data from group discussion, regulatory questionnaires, interviews, and task scores. Collect final metacognitive data from questionnaires.	Four weeks / cycle Grade 8 students
Dissemination of findings	Data collected during discussions with colleagues from various departments.	Every two weeks School-wide colleagues

Richards and Lockhart (1996) claim that action research "typically involves small-scale investigative projects in the teacher's own classroom, and consists of a number of phases which often recur in cycles: planning, action, observation, and reflection" (p. 12). Denscombe (2014) argues that action research should be used to "gain a better understanding of the problems that arise in everyday practice" and then actively seek to "alter things" (p. 122). Each action research cycle typically comprises four stages: scrutiny of the issues to be investigated, planning of appropriate interventions, subsequent execution of planned activities, and observation of the outcome (Cohen *et al*., 2010). Crucially, action research provides practitioners the opportunity to modify intervention strategies as the cycles continue.

My extended intervention duration provided my students with sufficient time to develop their assessment and feedback skills. Ross *et al* (2002) noted a similar finding when they carried out their study on the effects of self-evaluation on the problem-solving achievement of Grade 5 and 6 students. They confirmed that they had had less success with a previous similar study because it was too short (only 8 weeks), and that there was evidence that it had been "too short for teachers and students" (p. 53) who had been unable to develop the necessary language and confidence to assess themselves successfully. Their 2002 study, which occurred over a period of 12 weeks, showed an overall positive effect of self-evaluation on students' problem-solving capabilities.

The classroom-based intervention design

The intervention itself comprised several activities. Every Tuesday, my Grade 8 students were given a task to complete at home which consisted of an error-detection and a problem-solving activity. They had to complete this activity by themselves at home but could make use of any resources available to them, and had to show all their working, including planning. Before, during, and after the task, they had to complete a brief regulatory questionnaire which required them to explain their planning, monitoring, and reflection processes, as well as their metacognitive experiences. The following day, I carefully modelled the solutions to the problems, and their work was both self and then peer assessed. Then, every Friday, the students were given a very similar task to complete in class. Again, their completed work was both self and peer assessed using a comprehensive marking guideline document. Although they were required to give themselves and each other a numerical score based on the marking guidelines, this needed to be justified during both peer-feedback (as per the feedback guidelines presented in the literature review) and "self-feedback" which was facilitated by the regulatory questionnaire. An example of the weekly task and the regulatory questionnaire can be found in the Appendices. All assessments were formative, allowing students to experience regular low-stakes judgements which provided feedback and opportunities to reflect on and modify their subsequent behaviours and application of strategy.

Throughout the research period, my students were regularly reminded about the metacognitive strategies that could be employed during problem-solving. This was achieved using a Strategy Evaluation Matrix (SEM) which was developed by Schraw (1998) (the full SEM can be found in the Appendices) and which includes such actions as slowing down, re-reading, activating prior knowledge, mental integration, and use of diagrams (p. 120). In addition, their self-assessment activities included the identification of the strategies that they had used during tasks; the aim of this was to improve their Metacognitive Knowledge over time.

Collaboration

There were two main objectives to the collaborative efforts that occurred during this project: the first was to include my colleagues in the initial exploration phase so that I could ascertain the existing formative assessment practices within my school; the second was to regularly share my findings with my colleagues. In reference to the importance of collaboration in the action research process, Kemmis and McTaggart (1999) suggest that “the approach is only action research when it is collaborative, though it is important to realize that the action research of the group is achieved through the critically examined action of individual group members” (p. 5). In support of this premise, Burns (1999) asserts that “collaborative action research processes strengthen the opportunities for the results of research on practice to be fed back into educational systems in a more substantial and critical way” (p. 13).

My main collaborators were my Head of Subject, Mrs R, and another Grade 8 teacher, Mrs B, and they were both fully supportive of my research, and committed to assisting me where possible. They agreed that practitioner research is only fully beneficial when its methods, findings, and any resulting best-practice theories are shared within a professional community. They assisted me with the design of the intervention, and with the development of the observation framework and interview questions.

A crucial aspect of the collaborative element of my research was the regular dissemination of my findings, and subsequent discussions with my colleagues as to the efficacy and value of my intervention. This was done every two weeks at our staff development sessions. As these sessions are open to all members of staff, I was able to share my interim findings with a wide range of colleagues from a variety of departments. A teacher from the History department, Mrs V, had recently completed her Honours' degree in Education, and was able to provide valuable insights as to the practical implications of carrying out action research with a group of young teenage boys. Some of the findings from the discussions that took place at these sessions are presented in the next chapter of this thesis. For me, the most important feature of the collaboration that took place with my colleagues was the logistical and emotional support that was offered to me. This greatly mitigated the occasional feelings of isolation and bewilderment that resulted from undertaking research in a location many thousands of miles away from the university.

Methodology – methods for data collection

Strictly, this research is a mixed-methods design because it includes both quantitative and qualitative data (Denscombe, 2014). A mixed method approach and methodological triangulation can increase accuracy in research undertakings by checking for bias in research methods and providing opportunities to validate data (Cohen *et al*, 2010). Quantitative data was obtained via the metacognitive questionnaires which made use of a four-point Likert scale (from 'I always do this' to 'I never or almost never do this', or 'I strongly agree' to 'I strongly disagree', as required).

Qualitative data was obtained from the regulatory questionnaires, observation, group discussion, and individual interviews.

I elected to use questionnaires because they gave every student the opportunity to participate in the research project, and provided standardised data from identical questions. They are also quick to administer, and provide a comprehensive snapshot of the general views of the entire class. The metacognitive questionnaires were used to measure metacognition (the challenges and limitations of measuring metacognition are fully elucidated in the note in the next subsection). The regulatory questionnaire was completed by students concurrently with the problem-solving tasks and required students to reflect on their planning, monitoring and evaluation behaviours. It was based on a regulatory checklist that was created by Schraw (1998, p. 121) who argues that explicit, clear prompts can encourage students to be more “strategic and systematic when solving problems” (p.121). The purpose of the questionnaire was to encourage my students to think carefully about and then articulate the role of Metacognitive Skills (regulation of cognition) in their problem-solving tasks. Direct observation and post-assessment teacher questionnaires were used to obtain further data on the metacognitive behaviours of my students while they carried out their problem-solving tasks. This allowed me to increase the rigour of the quantitative measurement of metacognition in my students through the concept of “methodological triangulation”, whereby the findings from different methods can be compared to provide depth and contrast (Denscombe, 2014, p.154).

The metacognitive questionnaires (students’ and teacher’s) were completed by at the start of the research period (before the intervening action cycles), and then again at the end of the research period. Their results were used to monitor the efficacy of my approaches, and the ongoing development of my students’ metacognition. Desoete (2007) suggests that “teachers who are interested in metacognition in young children use multiple-method designs, including teacher questionnaires, to get a complete picture of metacognitive skills" (p. 706). The teacher's questionnaire can be found in the Appendices.

Semi-structured group discussions were also used to explore my students' views because of their discursive nature, offering students opportunities to express and explore their views than other more restrictive formats, such as the questionnaire. These discussions were recorded using my iPad. Finally, semi-structured interviews were conducted with five students which afforded me the opportunity to connect with my students in a non-threatening way. I decided to interview only five students, as the interviews were fairly time-consuming (about 30 minutes each), and I did not want to take an unnecessary amount of time from all of my students' busy schedules. The same five students were interviewed at the end of each research cycle (each student was interviewed three times in total). The interviews were semi-structured so that the questions could be adapted as needed. (Denscombe, 2014).

A note on measuring metacognition

Given the complex and multifaceted nature of metacognition, its measurement can be challenging. Many metacognitive proficiencies or deficiencies are not directly observable in students (Sperling *et al*, 2002), and many self-reporting methods, such as rating scales in questionnaire, rely heavily on verbal skills (Whitebread *et al,* 2009). 'Think-aloud' techniques may be problematic because students are not always able to identify implicit cognitive processes, and their metacognitive abilities may therefore be underestimated (especially when used with younger children) (Lai, 2011). Nonetheless, researchers and meta-analysts have been able to determine the relative advantages of some tools when measuring metacognition in younger children. Gascoine *et al* (2016) have developed a comprehensive and systematic review of numerous measurement tools based on their reliability and validity.

The metacognitive awareness inventory (MAI), which was developed by Schraw and Denison (1994) is considered by some to be a valid and reliable measurement for metacognitive knowledge and skills (Mevarech & Fridkin, 2006; Sperling *et al*, 2012). Sperling *et al* used the 18-item Junior Metacognitive Awareness Inventory (JrMAI) in their 2012 study and found that it correlated with teachers' ratings of student metacognition. I selected this questionnaire because it is easily available, is shorter and more accessible than many standard metacognitive questionnaires (such as the adult MAI which has 52 questions) and, according to Gascoine *et al* (2016), is suitably valid and reliable (p. 14). On analysis of the questions in the JrMAI, I found that certain components of metacognition were measured in greater depth than others; I thus decided to supplement it with a few additional questions from the original MAI. The final questionnaire that I used therefore consists of 29 questions.

The extended JrMAI measures both metacognitive knowledge and metacognitive skills; it is suitable for measuring general, but not subject-specific, skills. Therefore, to validate and reinforce the findings of the JrMAI, I decided to use a second questionnaire – the Inventory of Metacognitive Self-Regulation (IMSR), developed by Howard *et al* (2000) – which focuses specifically on the metacognitive knowledge and skills utilised by secondary school students during mathematical problem-solving, and which consists of 30 questions. The IMSR is similarly valid and reliable in measuring metacognition (Gascoine *et* al, 2016). The extended JrMAI and full IMSR questionnaires can be found in the Appendices.

Metacognitive Experience was measured before and after each in-class problem-solving and error-detection activity (once per week), and included the following specific questions (Efklides & Tsiori, 2001, p. 228):

- How difficult do you feel the task is (was)?
- How much effort do you think you need (needed) to exert in order to solve this problem?
- How correctly do you think you are going to solve (you solved) this problem?

These questions were added to the regulatory questionnaire. The answers were given on a four-point scale, ranging from very, to not at all.

Data analysis

The quantitative data from the questionnaires and observation schedule was analysed numerically for the purpose of comparison. Since my sample was very small (n = 15), there could be no statistical analysis, as the data obtained was statistically trivial. The numerical data was used purely to indicate the general change in the metacognitive skills and experiences of the 15 students in my class, and as a gauge of how the intervention, and my teaching practices, were impacting their learning experiences so that appropriate subsequent adjustments could be made.

The qualitative data collected from the group discussions and semi-structured interviews was analysed using a coding procedure. The recorded discussions and interview replies were transcribed and then an appropriate coding system was developed to facilitate meaningful comparisons and identify trends or anomalies (Denscombe, 2014). The coding system utilised the following categories: Metacognitive Knowledge, Metacognitive Skills, Metacognitive Experiences, Perr- and Self-Assessment.

Ethics

Although most of the intervention activities and data collection were carried out during the normal events of the school day, there are, nonetheless, essential ethical considerations that needed to be acknowledged and implemented throughout the research period. I carefully adhered to the British Educational Research Association's Ethical Guidelines for Educational Research. My research was carried only once informed consent had been obtained from all participants. Once approval for my study had been granted by the University of Oxford's CUREC committee, the aims, intervention, data collection methods, and implications of my research were clearly explained to my Headmaster, my Head of Subject , my collaborative colleagues, and the 15 students in the Grade 8 class who would be assisting me. Importantly, I selected one of my junior classes to assist with my research because their curricula are less onerous and demanding than those of their senior peers, thus allowing time and flexibility to utilise some lessons for group discussions and more in-class activities than usual.

The letter written to my Headmaster (presented in the Appendices) obtained written consent from him for the research to be conducted at the school, and within my Grade 8 class. Additionally, I obtained verbal consent from my Head of Subject to utilise some teaching time to carry out the nine tasks that were used for self-assessment, and to conduct group discussions. The individual interviews, which were done with five students, took place after school hours. The students that were interviewed were chosen randomly from my original sample and were required to give written consent to be interviewed. One student elected to opt out of being interviewed, and was replaced by another randomly-selected student who was more comfortable with participating.

Explicit written permission was also obtained from all fifteen of my Grade 8 students. I explained that they would be completing questionnaires, would be observed during problem-solving tasks, and that subsequent group discussions would be recorded on my iPad. They were given clear permission to withdraw from the research at any time, and understood that alternative arrangements would be made for them for the lessons during which intervention activities occurred, if they elected to opt out. They were also assured that their identities would remain anonymous this dissertation. It was made clear to my students that all questionnaires would be anonymous. As such, they each selected a special 'code name' (pseudonym) that they used to mark their own questionnaires so that I could compare pre-intervention and post-intervention results.

As I accumulated a large amount of data throughout the research period, I was compelled to keep this safely stored away until it was required for analysis. The written data was kept in a locked drawer in my office at school (which I share with a colleague) which was kept locked at all time. All electronic data was stored on my personal laptop and iPad which are both secured with a password, and which is kept at home. If I needed my laptop or iPad for my research work, I took them to school for those days only, and ensured that I carried my laptop bag and iPad around with me when I moved around the school. Finally, I have used the collected data from research only for the purpose of informing my findings, and I have been careful to exclude all opinions that were plainly revealed to me in confidence.

Findings and discussion

I will be presenting my findings thematically in order to allow for interpretation and links between the various methods used. The objective of a thematic analysis is to identify coherent patterns in the data that are significant or noteworthy, and use these themes say something valuable about an issue (Braun & Clarke, 2006). Summarising the data is not sufficient; a decent thematic analysis interprets it and then attempts to make some intellectual sense of it. Braun and Clarke (2006) define a top-down or theoretical thematic analysis, that is informed by the specific research questions and "would tend to be driven by the researcher's theoretical or analytic interest in the area" (p. 12).

Existing formative assessment practices at my school

The findings for this section were collected during a group discussion at a staff development session which took place during the exploratory phase of the research period. During the group discussion, most of the teachers who were present stated that they did not use very much formative assessment in their classrooms. Mrs C claimed that she was not sure what formative assessment is:

To be honest, I'm not even sure what it is exactly…I mean I know that it's assessing when it's not for marks, but I don't know more than that… It's when we do fun quizzes and portfolio pieces, I think.

Ms C

This view was corroborated by Mr V:

I think the last time I thought about formative assessment was when I did my PGCE, but that was….four years ago now. I don't think I really paid that much attention…I just studied it for the exam. The only time I do assessments is when we do class tests and exams…

Mr V

Generally, it was agreed that the focus of the school and the boys is formal, summative assessments which take place several times each term for all subjects. In fact, a few staff members suggested that the boys' interest in their grades was disproportionately intense. Their lack of interest in work that 'doesn't count for marks' is concerning to many. Of the 24 staff members who were present at the development session, 8 stated that they were not completely sure about what formative assessment entailed. Out of the other 16 staff members, 11 claimed that they did not use formative assessment in their classrooms. When asked why not, the majority agreed with Ms A:

I think it's about a lack of time in lessons, but also outside school. I think planning formative assessment and designing activities and things takes a lot of extra time which I don't really have to be honest. I'm already doing Hockey and marking every other day. It would just be too much.

Ms A

The five that do use formative assessment utilised either regular multiple-choice quizzes with their Grade 8 and 9 students on iPads, or gave their Grade 8 and 9 students a weekly informal test which they could use to gauge their current levels of learning and understanding. When the discussion turned to feedback, one teacher explained that, beyond marking the quiz answers right or wrong, there was no feedback given to students (unless a student specifically asked a follow-up questions); another said that, although she marks her students' informal tests herself and provides some written and verbal feedback, it was not comprehensive or consistent. When asked why, she (Ms S) stated:

Well, there's just no time. We barely have enough time to cover the curriculum, there's definitely not enough time to go over each question in detail…that could take a whole lesson, and then I'd have to catch up sometime, which is seriously stressful. It's just not worth it.

Ms S

Further, other opportunities for 'good feedback practices' to be implemented, such as while homework was being marked, or when summative assessments were returned to students, were viewed by the majority of the teachers as "too time-consuming" and "rather boring for the students because they barely pay attention". These findings paint a clear picture about the general view of formative assessment at my school. Most do not consider it to be a necessary or useful part of a well-designed lesson, and do not believe that it could be materially beneficial to their students. Additionally, many are greatly concerned about the lack of academic time that they have with their students, particularly the senior students.

These findings confirmed the potential value of my research project, not only for my own practice, but within the context of my school. The lack of systematic formative assessment practices in my colleagues' classrooms highlights a possible disconnect between what is taught and what is learnt. Although resulting gaps can be highlighted and closed through summative assessments, it is possible that, in some cases, limited effort is being made to identify them earlier, while learning is taking place. It became clear to me that the discussions around these topics needed to continue within my school, and that it was especially important to disseminate, as widely as possible, my findings during and after the implementation of my intervention.

Peer- and self-assessment

The findings on peer- and self-assessment were collected through whole-class group discussions and reflective questionnaires, which both occurred weekly, as well as individual interviews, which took place at the end of each research cycle.

Findings that resulted in changes to the intervention

A defining feature of the first research cycle was my considerable involvement in defining learning objectives and creating marking guidelines, as well as in the monitoring of their assessment practices to ensure that they were generally adhering to the recommended procedures. A notable finding in the first cycle was that, as my students became more proficient at marking their work, many expressed dissatisfaction with the marking guidelines that I created, which they believed to be too rigid, and did not award points for planning, clarity, and working details.

My students' concerns about the marking guidelines are in line with literature which posits that when objectives and guidelines are developed by both students and teachers, there is more buy-in from students who then also have a better understanding as to what is expected from them (e.g. Andrade, 2010; Nicol & Macfarlane-Dick, 2006; Wiliam, 2010). The consequence of this finding was an iterative process of modifying the marking guidelines until most of the students were satisfied with the result. The final draft was more akin to a rubric, and allowed a maximum of five points for mathematical accuracy and appropriate application of strategies, three points for showing planning and a worked solution, and two points for neatness and clarity. The marks were awarded by my students as they saw fit (still with the assistance of a worked solution guideline), and the need for my assistance was drastically reduced. They thus became more independent, and their overall response to the self- and peer-assessment activities became more positive.

Group discussions and individual interviews conducted in the first research cycle revealed that several of my students were concerned about their lack of abilities in implementing effective self- and peer-assessment, and noted the discrepancies between the score (out of 10) that had been awarded by their peer and that which they had awarded themselves. This appears to be a common concern in novice assessors, as confirmed by Topping (2010), who argues that initial anxieties can be alleviated, and improvements in practice can be promoted, by monitoring the process, coaching, and initially examining the quality of the feedback.

This resulted in a minor change to the assessment process for the second and third cycles: each problem-solving task was also assessed by me using the same marking criteria as the boys. My score had to be justified using the requisite peer-feedback guidelines, and it was used in conjunction with my students' own evaluations to provide a more reliable and valid overall assessment of each task. I continued to score their work for all of the research cycles, but allowed them to view my feedback only in the first cycle. I then faded my scaffolded support out during the last two research cycles. The score evaluations of my students' tasks provided quantitative data that allowed me to compare the discrepancies between self-, peer-, and teacher-assessments, and to examine the changes in their own assessment capabilities over time. This comparison provided further insight into the changes in metacognition of my students over the course of the study.

General findings over the course of the study

The group discussions during the first cycle revealed that most of my students had rarely carried out systematic peer- and self-assessment, and they thus initially found it challenging to implement the required processes. Although they regularly marked their own homework, and occasionally evaluated each other's activity worksheets, this superficial assessment occurred in an ad-hoc manner, and, notably, without clear guidelines or subsequent feedback. As one student commented:

Mostly we've just marked things right or wrong….I don't think there was any point to it really except maybe that the teacher didn't have time to mark it herself. But we don't really do it often, except in History maybe, but that's a lot of multiple choice so it's quite easy to mark.

Student F, group discussion

We work in groups sometimes but, not like marking each other's work in detail like this where we have to say what was good and what was bad, and why and everything.

Student B, group discussion

The concerns about the lack of feedback from these peer- or self-marking activities was articulated by Student M:

Ma'am, what's the point in doing it? It's not like it helps us or anything. We never get a chance to understand where we went wrong. It's much easier if the teacher marks it and then we know exactly how badly we did. **Student M, interview**

Even at the age of 14, Student M is aware of the futility of an activity that requires considerable effort from him, but which adds no obvious value to his learning journey. In voicing this concern, he is articulating the value of feedback in the formative assessment process. In fact, assessment without qualitative feedback cannot be formative because there is no information for the students (and teacher) to use for decisions on how to improve. Although my students often seem fixated on their numerical results, this comment gave insight into the fact that many students seek more comprehensive commentary on the strengths and weaknesses of their work. This is in line with Clark's (2012) claim that "feedback is pivotal to formative assessment and therefore to the development of self-regulated learning strategies among students" (p. 3). A noteworthy comment from one of my students was that most of them felt frustrated that the outcomes of their formal assessments in all subjects were seldom examined in detail after the fact, and the feedback they did receive was usually cursory, which made it "difficult to know how to improve in the next test". This triggered a discussion with my Head of Subject who confirmed that there was no clear policy regarding test and assignment feedback, and that this was an area of weakness within the department. We agreed that the topic of feedback quality and delivery needed to be further examined going forward.

Changes in peer-assessment and peer-feedback over time

As already indicated, most of my students initially struggled with the processes of assessing their own and their peers' work. Several were reluctant to 'judge' their peers' work, and felt that they were not capable of doing so 'correctly'. Data collected from group discussions and individual interviews give some insight into these concerns:

How can I rate his work, it's not like I know what I'm talking about….I'm not even good at maths, how can I must mark someone else's? I just hope I don't say something stupid.

Student B, interview

In fact, at the start of the study, three out of the five boys that I interviewed voiced their concerns about their lack of competency is assessing both their own and their peers' work. The most common reasons given were that they did not always know "what was good and what was bad" about the work, and that they struggled to explain to their peers "how to do better next time" due to their own lack of ability or awareness. After the first assessment activity, only 3 out of 15 students believed that the process of assessing their peers' work had been beneficial. In comparing the numerical scores that they gave their peers with those that I gave them for the first problem-solving task, there was a 20% or higher differential in 10 out of 15 cases. This improved over time, as shown by the following charts 1 and 2.

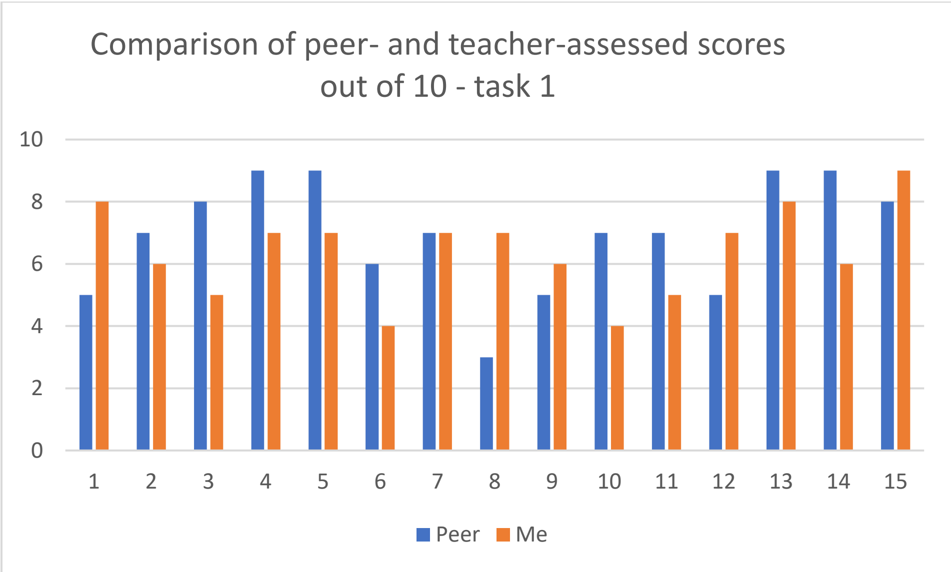


Chart 1

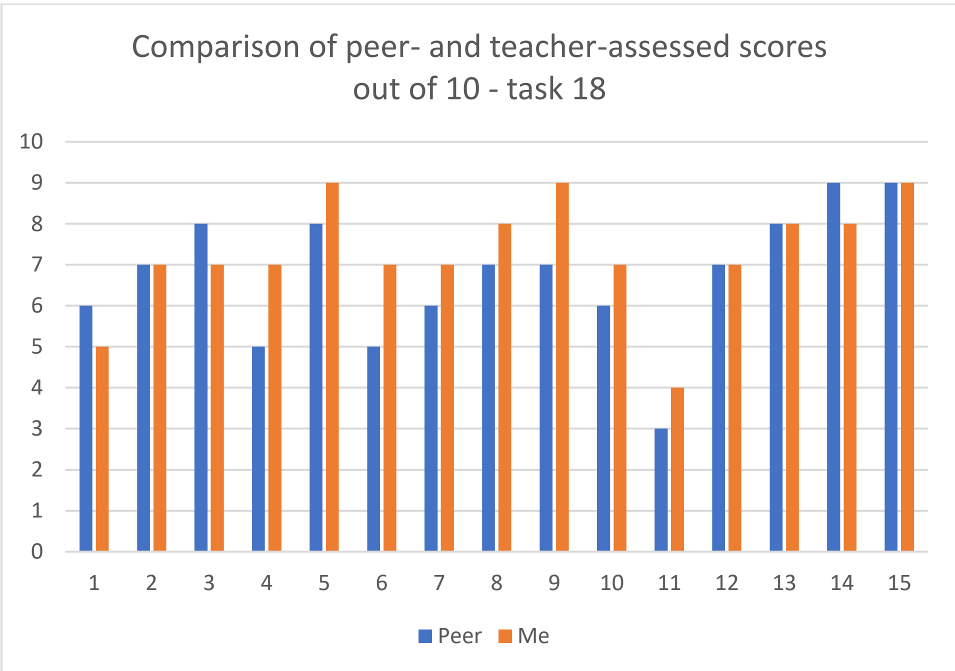


Chart 2

By the end of the study, the differential had reduced materially, and the number of cases for which the differential was greater than 25% was 4 out of 15. This improvement correlated with two other events: improvement in numerical scores (most likely reflecting problem-solving ability), and improvements in metacognition. In other words, on aggregate, as my students' problem-solving skills and metacognitive awareness improved, so did their ability to assess their peers' work. Interview data revealed that all five students felt "more confident" in their abilities to assess their peers' work over time, while discussions confirmed that 12 out of 15 students felt that the process of assessing their peers' work was positively impacting their abilities to solve mathematics problems, and assess their own work effectively.

My students' lack of experience initially impacted their abilities to generate meaningful verbal peer feedback. This also changed over time:

Regarding peer feedback after the first cycle:

Also, I don't know how to say what I mean. It's hard to put what I'm thinking into words. And, actually, I don't really know why things are wrong or what they should have done differently.

Student E, interview

It's hard to criticise the work without hurting people's feelings. I'm not really enjoying it.

Student L, group discussion

Some students had contrasting views, and could already identify the benefits:

It gives me a chance to see things through his eyes, so I can….get a different view of my work. We have been having good discussions and have been learning from each other.

Student H, group discussion

When I have to try to explain where he went wrong, it forces me to think about things more... And also to see that sometimes he does things a different way which gives me ideas about how to do things next time.

Student G, interview

Regarding peer assessment and peer feedback after the final research cycle:

It's a lot easier now…I understand how it works now and think I'm better at telling (him) where he went wrong. I still don't really enjoy it though. **Student L, group discussion**

I think it's getting easier to show (him) how he could have done it differently….and it also helps me to understand what I sometimes do wrong. Sometimes we make the same kind of mistake but it's easier to see it when you work with someone else.

Student B, interview

These improvements and changes of view occurred as my students learned how to establish constructive dialogues about each other's work, and as they developed a better grasp of the problem-solving and general mathematical strategies that they could use. 11 out of 15 students also agreed that the act of articulating the strengths and weaknesses of their peers' work became easier over time, while 10 out of 15 believed that it benefitted them in developing a deeper understanding of the flaws of their own work and in thinking about how they would solve a similar problem in the future. The benefits and improvements were as a result of many weeks of practice, and effort on all our parts to foster an environment of support for each other's learning.

In discussions and interviews, the following attributes of peer-assessment and feedback emerged as the most valuable: the opportunity to use the feedback proactively to make improvements in similar future tasks, and the opportunity to actively discuss their evaluation with the person that carried it out. My students greatly appreciated being able to use the feedback to modify their future behaviours and efforts. However, an examination of all the qualitative data that I obtained during whole-class discussions and interviews revealed that, overall, they believed the greatest benefit came from the conversations that arose as a result of the assessment and feedback process. During the final research cycle, one student claimed that he had come to value his peer's qualitative feedback more than the numerical score that he had given him. He stated that "when he shows me where he thinks I went wrong, and what he thinks I could have done better, I'm really listening now, and then when we discuss it…I think it's making us both think about things more". Indeed, while most of the initial feedback was brief and sparse, by the end of the final research cycle, it had become richer and more critical for 9 out of 15 students.

Changes in self-assessment and reflection

In much the same way as experienced during peer-assessment, many of my students struggled to self-assess effectively at the start of the research project:

I'm not sure I can do this right. I think I might be marking my work too high, like if you were marking it, I'm sure I'd be doing way worse than that. **Student G, interview**

Like student G, four out of five of the students that I interviewed stated that they believed that they were not able to assess their work "properly". The fifth student did not voice any concerns, and claimed to feel quite comfortable with the process and sure of the scores that he was giving himself. Interestingly, this boy is academically and metacognitively weaker and I realised that he could be presenting some lack of awareness of his assessment abilities. Further examination of his regulatory questionnaire and reflection writing revealed that he was overstating his abilities and that his scores did not reflect the actual level of his problem-solving abilities. To add to this, there were significant discrepancies between his own scores (and feedback) and those awarded by me. Further examination revealed that this was a trend amongst my students: four of my five lower-ability students and three of my five average-ability students initially rated their own abilities and task outcomes higher than I believed they should be.

This demonstrated one of the limitations of my intervention, and provided some evidence to support the criticism that weak students are more likely to be poor assessor's of their own work (e.g. Andrade, 2010; Kruger and Dunning, 1999). Kruger and Dunning suggest that "overestimation occurs, in part, because people who are unskilled in these domains suffer a dual burden: Not only do these people reach erroneous conclusion….but their incompetence robs them of the metacognitive ability to realise it" (p. 1121). There thus exists the concern that in not being able to discern the deficiencies of their own work, and the possible causes thereof, metacognitively weak students may not benefit from the process of self-assessment as much as their metacognitively stronger peers. Andrade (2010) argues that "students who struggle with school-work need extra help understanding their tasks, the criteria for them, and the self-assessment process" (p. 101). It therefore became particularly important for me to focus on my weaker students while facilitating the self-assessment activities, and to give them explicit feedback as to the areas that required more effort, or a different approach. As already stated, this was achieved by the concurrent provision of my own scores and feedback until their confidence improved. By the end of the study, their confidence in their abilities had improved: 3 of my 5 low attainers believed that they were better able to utilise self-assessment activities to identify their own strengths and weaknesses and target areas for remedial action.

Overall, qualitative analyses of written assessments and rubrics indicated that there were improvements in the self-assessment abilities of many of my students (10 out of 15) over the course of the study. This finding was verified by a quantitative analysis of the average percentage differentials in the task scores (out of 10) awarded by themselves and me: they decreased by an average of 28% over the course of the study. An improvement in self-assessment skills may be indicative of an increase in metacognition and self-awareness. This measured improvement in self-assessment skills correlated positively with the following: enhanced peer-assessment skills, refined metacognitive knowledge and skills, and improved problem-solving capabilities.

Similar findings emerged from the self-reflection activities. The results of these questionnaires comprised written answers to questions about planning, monitoring, and evaluation of problem-solving tasks. These were answered poorly by all of my students at first: many questions were simply not answered, or the answers that were provided were one-worded and often had little connection to what was being asked. Many of my students felt initial discomfort at the notion of judging their own work qualitatively, as well as quantitatively. The requirements to justify the scores they had given themselves, to overtly identify strengths and weaknesses, and to provide guidance to themselves as to how they could improve going forward, proved to be challenging. Discussions confirmed that, besides the problem-solving task itself, this was the aspect of the process that they struggled with the most. Reasons given ranged from "It's too much writing", to "I don't know what the question is asking" and "I just don't know how to say what I think I want to say". Most admitted that in Primary School they had only rarely been required to overtly think about or comment on their work in a similar way.

Initially, the questions about planning, which asks questions such as "What is my goal?" and "What is the nature of the task", were answered more successfully, while those regarding monitoring and evaluation were poorly indeed. A similar study conducted by Ross *et al* (2002) found that "teachers reported that students were reluctant to self-evaluate in mathematics because they lacked the key terms for describing their work, they were anxious about the subject" (p. 53). While the same was true for most of my students, the strategy evaluation matrix, together with regular guided practice, precipitated improvements over the course of the research period. In my own analysis of their reflection questionnaires, I found that all fifteen of my students presented some improvements in their self-reflection abilities over time: the greatest improvements were seen in my weaker students (who started from a low initial base measurement), and in the questions on evaluation. The questions on monitoring improved least, indicating that most Grade 8 students continued to struggle with the process of thinking about what they were doing while they were doing it. It is possible that with additional support, time, and practice, students could improve here as well, as argued by McMillan and Hearn (2009): research indicates that consistent on-going practice with self-assessing aids students in mastering the task, and makes both the learning task and the process of self-assessment more meaningful.

In group discussions towards the end of the study, 12 out of 15 students stated that they believed their self-assessment and self-reflection skills had improved, and 10 out of 15 felt that the process of self-assessing and self-reflecting was promoting their abilities in strategic problem-solving. When probed as to why they believed their reflection skills had improved, the two most common reasons given were “we’ve had lots of chances to practice, so we know how to do this now”, and “we’ve been able to talk about the questions with you and our partners”. This confirmed the value of community and discourse in allowing younger students to develop their thinking around their own thinking, their abilities, and their strategy application techniques. This finding is corroborated by Andrade (2010), who found that “there is ample evidence that they can accurately self-assess and self-regulate under the right conditions” (p. 99).

In discussions and interviews, the following attributes of self-assessment emerged as the most valuable: its anonymity, and its formative nature - the fact that the evaluations were never counted towards a formal grade. It again became clear that my students sincerely valued the opportunity to use their self-assessments to make improvements in future assignments. Supporting students in closing the gap between where they are and where they would like to head to is what makes formative assessment and feedback powerful (e.g. Hattie and Timperley, 2007), and there is evidence (e.g. Andrade, 2010) that even young children are able to regulate their behaviour and learning after analysing the results of a “nonthreatening assessment” (p. 97).

One unexpected finding during the interview process was that of overall reduced anxiety with the assessment process. This was raised by two of the five interviewed students. While they admitted that they had been anxious and concerned before the first few tasks, even though they were aware that the scores were for formative purposes only, they then acknowledged that their anxiety had been reduced over the course of the study. Further discussions with the whole class confirmed that 'maths anxiety' had been experienced by 9 out of the 15 students during the first few problem-solving activities, but by only 4 out of 15 by the final task. This was a positive finding, and may indicate that my students came to realise that the assessment activities were genuine opportunities to practise their mathematical skills, introspect on the resulting outcomes, and learn from the errors in both their own and their peer's work. This finding is supported by results obtained in numerous studies which confirm that anxiety around mathematics assessments is greatest when they are high-stakes (Geist, 2010). This more positive attitude towards problem-solving and self-reflection could improve learning outcomes, and is substantiated by studies (e.g. Sarıcam *et al*, 2015) which found that maths anxiety is negatively related to metacognitive awareness

Metacognitive knowledge and skills

Data about my students' metacognitive knowledge and skills was obtained by means of the metacognitive questionnaires, the teacher questionnaire which was based on observation of student behaviours and actions during problem-solving activities, and individual interviews of five students. The questionnaires were completed by my students before the first research cycle took place, and then again 14 weeks later. The comparative numerical outcomes of each questionnaire will now be presented.

The questionnaires on metacognitive knowledge and skill

For the purposes of analysis, I will present the overall findings of the two questionnaires, and will then delineate the findings in order to consider the changes in metacognitive knowledge (MK) and metacognitive regulation (MR) over time. The extended JrMAI comprises 29 questions about general metacognition, while the IMSR comprises 30 questions about domain-specific (here, mathematics) metacognition. Table 1 summarises the overall data obtained from the JrMAI, and Table 2 shows the IMSR results. In both tables, the data from both before and after the 14-week research period is presented. For both sets of data, the data is measured on a 4-point scale with a '1' indicating that metacognitive knowledge and regulation skills are never (or almost never) used, a '4' indicating the metacognitive knowledge and skills are always (or almost always) used.

Overall JrMAI results – before study					**Overall JrMAI results – after study**				
Rating	**1**	**2**	**3**	**4**	**Rating**	**1**	**2**	**3**	**4**
Total number	60	168	151	56	**Total number**	25	159	192	59
Mean score	2.47				**Mean score**	2.66			
Median score	2				**Median score**	3			
Standard deviation	0.88				**Standard deviation**	0.78			

Table 1: Comparison of JrMAI questionnaire results from before and after the study

Overall IMSR results – before study					Overall IMSR results – after study				
Rating	**1**	**2**	**3**	**4**	**Rating**	**1**	**2**	**3**	**4**
Total number	82	210	116	42	**Total number**	46	151	218	35
Mean score	2.26				**Mean score**	2.54			
Median score	2				**Median score**	3			
Standard deviation	0.86				**Standard deviation**	0.81			

Table 2: Comparison of IMSR questionnaire results from before and after the study

The combined results from both questionnaires show a small increase in the mean score of the results measured before and after the full 14-week study. The mean score of the extended JrMAI increased by 7.64%, while that of the IMSR increased by 12.18%. It is interesting that, overall, my students' general metacognitive skills (as shown by the JrMAI) were initially measured to be better than their domain-specific skills (as shown by the IMSR). This could be a manifestation of the theory of metacognitive development, according to which, domain-specific skills develop at a later stage (usually age 13-14) than those that are more general (Veenman *et al*, 1997). My results indicate that it is likely that some of my weaker and younger students started the study with low domain-specific metacognition. It is also likely that the greater increase in the mean scores of the IMSR questionnaire (compared to that of the JrMAI) was due to the ample practice that my students had in utilising metacognitive knowledge and skills specifically during mathematics problem solving activities.

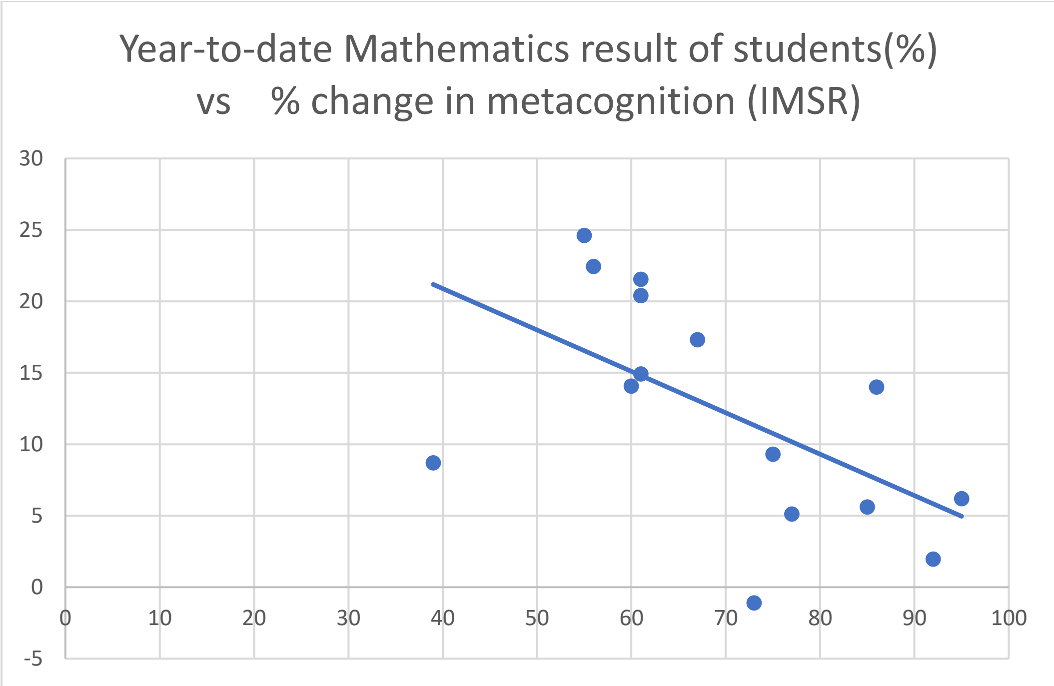
A more detailed examination of the quantitative data reveals that 14 of my 15 students experienced a positive overall change in their measured general metacognition (as measured by the JrMAI), while one student's measured metacognition decreased (by 2.4%). Similarly, 14 of my 15 students experienced a positive overall change in their measured domain-specific metacognition (as measured by the IMSR), while one student's measured metacognition decreased (by 1.1%). The measured percentage change in the metacognition of all of my students over the 14-week study is summarised in Table 3.

JrMAI results – % change		**IMSR results – % change**	
% change	**Frequency**	**% change**	**Frequency**
Negative	1	**Negative**	1
0 - 10	9	**0 - 10**	6
10 - 20	3	**10 - 20**	4
20 - 30	2	**20 - 30**	4

Table 3: average percentage change of measured metacognition over 14 weeks

These measured results confirm that more students exhibited positive changes of more than 10% in their domain-specific knowledge and skills than in those of the general domain. This may be a result of the focused time spent on specific mathematics problem-solving tasks, while the type (and frequency) of activities and assessments in other subjects remained unchanged. It is, however, notable that tasks that requires students to monitor their actions and thinking, and then self-reflect on the outcomes, appear to have a positive impact on general metacognition. This may be beneficial in all spheres of my students' learning by encouraging them to think carefully about what a task requires, how they plan to meet task and learner expectations, what strategies they could apply, and how they might compensate for their academic weaknesses using their known strengths.

The greatest positive change in the JrMAI measurements was 29.8%, and occurred for a student who is an average achiever in mathematics but who consistently exhibits low self-esteem and is vocal about his apparent lack of mathematical abilities. His average score improved from 1.62 to 2.1. The low base from which the change was measured is probably more an indication of his initial beliefs that he was incapable of metacognitive actions than a reflection of his actual skill level. The relatively large improvement over the course of the study suggests a positive change in both his self-concept and his general metacognition. Conversely, the small negative change occurred for a student who is a high-achiever but is prone to overstating his abilities. The greatest positive change in the IMSR measurements was 22.5%, and occurred for a student who is a low achiever in mathematics, and who is aware of his deficiencies. He came to my class late in the year and was still catching up academically with the rest of the class while my research was taking place. His average score improved from 1.63 to 2.0. The low base from which the change was measured is probably a realistic reflection of his metacognition in a mathematics context, while the improvement over the course of the study suggests a notable positive change in his metacognitive knowledge and skills during problem-solving. In general, my weaker students presented a relatively larger positive change in their measured metacognition. This is illustrated in Graph 1, which suggests a generally negative relationship between overall mathematical ability (as measured by formal summative assessments) and relative percentage improvement in metacognition. This suggests that many of my weaker students in particular benefitted from the intervention. While many of my stronger students already presented with some well-developed general metacognitive skills at the start of the study (e.g. articulating objectives, checking work), my weaker students saw measurable gains in these (manifesting as changes in behaviours) over the 14-week study.



Graph 1

When the results are delineated into metacognitive knowledge and metacognitive regulation measures, the evidence shows that my students' metacognitive knowledge was initially greater than their regulatory skills. This finding is similar to that of Desoete *et al* (2001), who found that, "from a developmental point of view metacognitive knowledge precedes metacognitive skills" (p. 436). Although the percentage improvements were technically greater for the regulatory than the knowledge aspects of measured metacognition, they were too small to draw any meaningful conclusions: the mean metacognitive knowledge score of the JrMAI increased by 7.31%, that of metacognitive regulation increased by 7.84%, and the IMSR shows an increase in the mean score of metacognitive knowledge of 11.07% and of metacognitive regulation of 12.57%.

Overall, these results are in line with numerous studies (Tanner, 2012; Clark, 2012; Pantiwati *et al*, 2017; Schraw, 1998; van der Walt & Ellis, 2012; Siegesmund, 2016), which have found that metacognitive training, together with peer- and self-assessment and self-reflection, can have a positive effect on the metacognitive knowledge, skill, and regulation of students. These results cannot be generalised due to the small sample size of my study, but it appears that, with sufficient support and formative feedback, my Grade 8 students were able to improve aspects of their metacognition. Siegesmund (2016) suggests that students who “incorporate external feedback and generate more internal feedback tend to be more effective at regulating their learning” (p. 212), and this held true for my students who showed a notable increase in their metacognitive regulation skills after 14 weeks of combining externally-generated peer feedback with internally-generated reflections on the planning, monitoring, and evaluation activities that they implemented while solving problems.

These findings were further substantiated by data from the individual interviews that I conducted with five students at the end of each research cycle. The two academically weakest students experienced similar variations in their metacognitive capabilities throughout the research period. While both were over-confident of their metacognitive abilities at the start of the study, their awareness of their abilities improved over time so that they were able to discuss their realisation of their relatively poor planning, monitoring, and evaluation skills.

I think maybe I didn’t really know what I was doing at the beginning…things make a lot more sense now. Like, I think I’m getting better at understanding where I went wrong, and what I’m doing well…definitely more than before. **Student G, interview, end of study**

For the other three students, their metacognitive progress was slightly more linear: they described their metacognitive abilities as generally improving from one cycle to the next. This further strengthens the hypothesis that students who have poorer metacognitive skills are often less able to accurately measure their metacognition, and thus reduces the validity of the initial measurements of metacognitive knowledge and regulation. However, as metacognition improved, my students’ awareness and judgement of their own metacognition was enhanced, thus increasing the accuracy of the metacognitive questionnaires. This was reflected in the data presented in tables 1 and 2: although the number of students who believed they never applied metacognitive knowledge and regulation decreased materially over time, the number who believed they always did, did not similarly increase. This could explain the reduction in the spread of the self-measured metacognitive scores over time (indicated by the standard deviations) – there was a marked overall reduction in the number of '1' and '4' scores, and an increase in the number of students who believed they utilised metacognitive skills 'sometimes' or 'often'. This is similar to Siegesmund's findings (2017), which showed that because the process of self- and peer-assessment increases metacognition, students become more proficient at evaluating their own skills and progress over time, while Isaacson and Fujita's (2006) study found an increased accuracy of self-evaluation of metacognition as metacognition itself improves over time.

It should be stated that not all of my weaker students experienced initial overconfidence in their abilities. Group discussions revealed that two of them were very aware of their lack of metacognitive skills, particularly at the start of my study, which had a two-fold effect: it resulted in feelings of inadequacy and anxiety which made them reluctant to participate in the research activities, and it reduced their efficacy in assessing their own work and in rating their metacognition. This was not because they overestimated their abilities, but because they were simply too unaware of their own abilities to competently grasp the meaning and implications of the queries that they were required to comment on. Their initial metacognitive questionnaires were thus probably poor indicators of their actual knowledge and skills.

The final method for collecting data on the metacognition of my students was my own measurements which were taken using the Teacher Questionnaire developed by Desoete (2007).

This was completed at the start of and then again at the end of the research period. Although the risk of observer's bias was a potentially limiting factor of these measurements, it was nevertheless important that they were taken. Desoete herself asserts that "teachers who are interested in metacognition in young children use multiple-method designs" (p. 717). Pintrich (2002) argues that, as metacognitive skills are explicitly discussed and taught in the classroom, "teachers will become aware of the general level of metacognitive knowledge in their classrooms and will be able to judge fairly quickly the level and depth of students' metacognitive knowledge" (p. 224).

The 20-part questionnaire was completed using a 4-point rating scale. The measurements were based on two activities: observation of students while they worked to solve mathematical problems, and analysis of their worked attempts thereafter. The results are summarised in Table 4.

Teacher questionnaire results – before study					**Teacher questionnaire results – after study**				
Rating	**1**	**2**	**3**	**4**	**Rating**	**1**	**2**	**3**	**4**
Total number	88	146	58	8	**Total number**	47	118	109	26
Mean score	1.95				**Mean score**	2.38			
Median score	2				**Median score**	2			

Table 4: Comparison of teacher questionnaire results from before and after the study

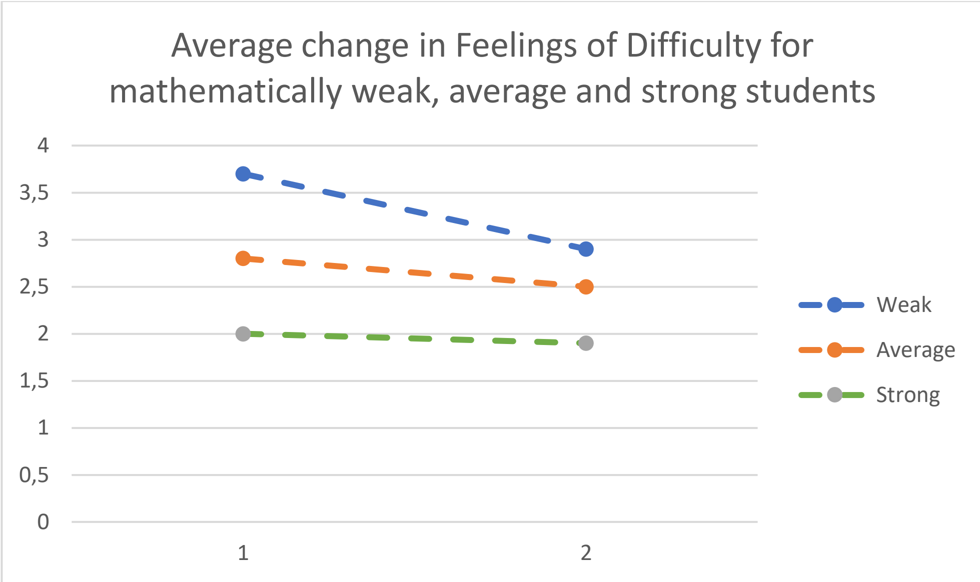
My initial measurements of my students' overall metacognition were measurably lower than those estimated by their own efforts (JrMAI mean of 2.47; IMSR mean of 2.26). This is possibly due to the overestimation of capabilities by students with lower initial levels of metacognition. My final measurements were still slightly lower than my students' (JrMAI mean of 2.66; IMSR mean of 2.54), but I found an overall increase of 21.84% which was greater than that indicated by the JrMAI or the

IMSR. My own findings therefore substantiate my students' measurements of their own metacognition: there was an overall increase in my students' metacognition over the course of the study. There is thus further evidence that the following factors can increase to metacognitive awareness: teacher-led instruction and guidance, self-assessment and reflection, and peer-assessment with feedback. A complete spreadsheet of all data can be found in the Appendices.

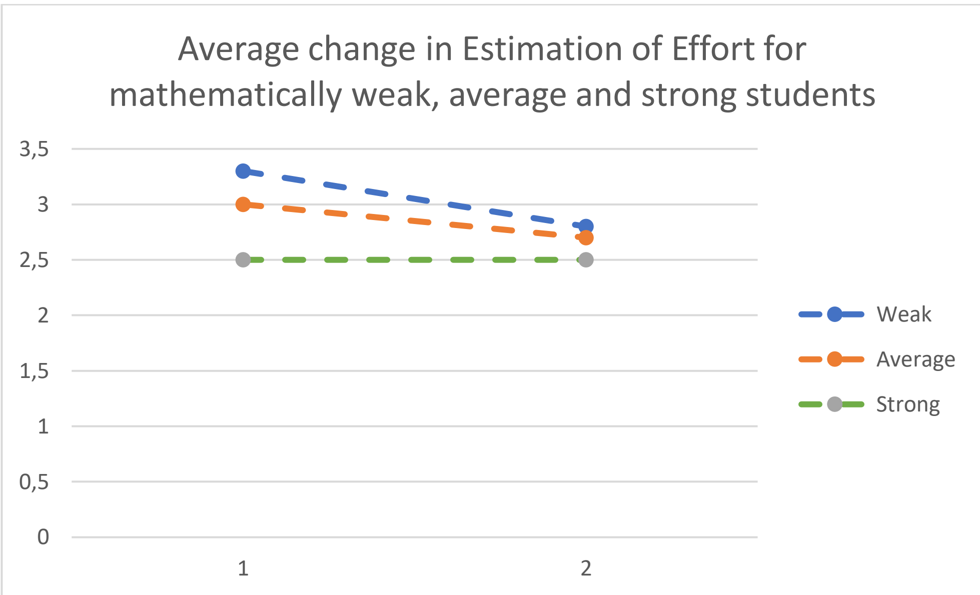
Metacognitive experience

The metacognitive experience of my students (ME) was measured on a weekly basis as part of the regulatory questionnaire that they completed before, during, and after each problem-solving task carried out at home. The full questionnaire can be viewed in the Appendices. The questions focused on three aspects of ME: feelings of difficulty (FOD), estimation of effort required (EOE), and, assessment of success in the given task (estimate of confidence, EOC). I decided to include the measurement of ME in my study because it is an important indicator of my students' task-specific self-concept, which could affect their overall ability to self-regulate their learning and achieve academically in mathematics (Efklides & Tsiora, 2002; Efkildes, 2017), and, is also an "indispensable link in the cycle of self-regulation" (Efkildes & Tsiora, 2002, p. 233).

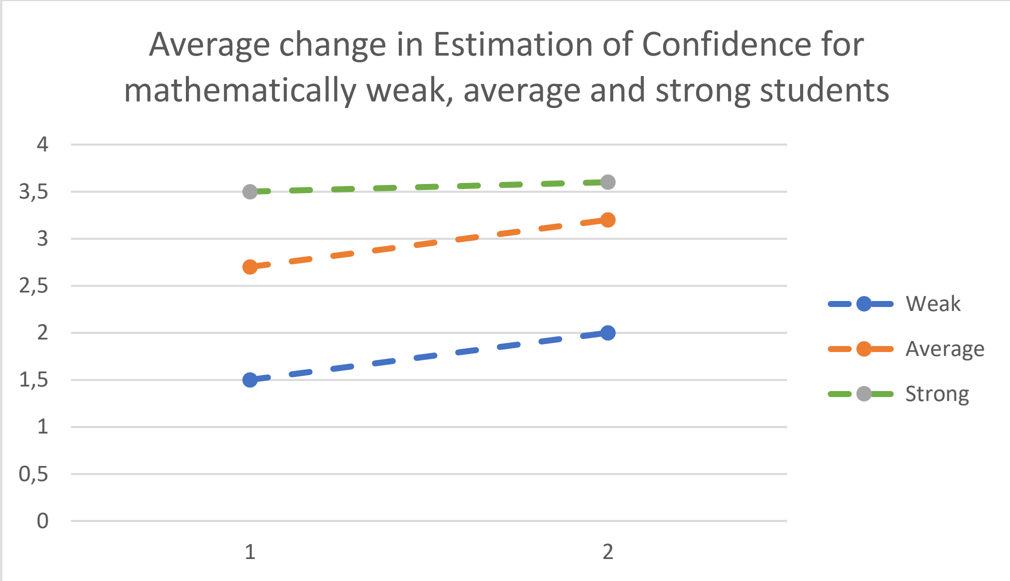
Graph 2 shows the overall changes in Feelings of Difficulty for my four weak, six average, and four strong students. Graph 3 shows equivalent changes in Estimates of Effort, while Graph 4 shows changes in Estimates of Confidence. I obtained these results by taking their average ratings of each component for the first task, and then doing the same for the final task. The problem-solving tasks were designed to of similar levels of difficulty (as rated by me).



Graph 2



Graph 3



Graph 4

A more detailed analysis of the data revealed that the feelings of difficulty reduced or remained the same over time for all except three students. This suggests that students found the problem-solving and error-detection activities easier over time, as their strategy applications and metacognitive skills improved. Since FOD is strongly related to the actual task (Efklides & Tsiori, 2002), this supports the hypothesis that the majority my students were genuinely becoming more competent over time. Interestingly, two of the students whose feelings of difficulty increased over time are academically string (in mathematics). My view is that these boys initially either wanted to indicate to me how easy they found these tasks, or had an unrealistic and overconfident view of their abilities in solving mathematics problems. As they completed the ME questionnaires more regularly, and became more metacognitively aware and honest, their measured feelings of difficulty increased slightly.

Unexpectedly, only eight of my students experienced an increase in the estimates of their confidence. For the others, their EOC remained the same, or reduced slightly. This suggests that the intervention had only a trivial effect on the feelings of confidence of many of my students. Efklides and Tsiori (2002) claim that FOC is strongly linked to maths self-concept, and less so to actual academic performance. My students' maths self-concepts have been formed, established, and modified, for over 13 years, and are thus a significant component of their beliefs and experiences in the mathematics classroom. Although a 14-week study was able to positively impact some of their metacognition, as well as their formative assessment skills, it was less able to change their entrenched views of their own mathematical efficacy. This suggests that it would take more rigorous efforts over a longer period of time to improve the maths self-concepts of some of the weaker students in my class. This, in turn, speaks to the fact that, for some of them, the road to becoming fully self-regulated learners will be paved with obstacles. Improved metacognition on its own is not sufficient to improve their abilities to regulate their learning and attain academically; reduced anxiety and greater self-confidence will also be necessary.

CONCLUSION AND IMPLICATIONS FOR FUTURE PRACTICE

Summary of findings

The findings can be summarised with reference to the research questions.

What are the existing formative assessment practices within my school?

Most of my colleagues do not utilise formative assessment effectively in their classrooms, and are unaware of its potential benefits. The feedback they provide is often rushed and brief which reduces the opportunities for their students to utilise it for the modification and improvement of future academic tasks. There is a strong focus on summative, high-stakes assessments in my school, and some of my colleagues do not want that to change. However, the discussions that we have had at our staff development sessions has increased awareness of formative assessment and feedback, and a few colleagues have committed themselves to incorporating these into their classrooms.

Does the implementation of self-assessment and peer-assessment practices have a positive effect on the metacognitive knowledge and skills of students?

For the majority of my Grade 8 students, yes. Self- and peer-assessment practices can have a positive effect on some of the metacognitive knowledge and skills of many students, but only with significant levels of practice, time, and effort. While both general and domain-specific metacognitive attributes were positively affected by the formative assessment activities, slightly greater changes were observed in those associated with mathematical skills. The problem-solving activities that we performed, and the subsequent assessment and reflective exercises, appeared to have a slightly greater influence on the regulatory abilities than the metacognitive knowledge of my students. Academically weak students showed greater overall improvements in their metacognition as a result of self- and peer-assessment activities. It appears that the discourse that results from peer-assessment activities is as important for the development of metacognitive awareness as the over acts of self-assessment and self-reflection.

Does the implementation of self-assessment and peer-assessment practices impact the metacognitive experience of students?

It can, but the extent of impact is dependent on their existing academic abilities and maths self-concept. Many of my students were able to improve their feelings of difficulty over time, and with practice, but only some experienced positive changes to their feelings of confidence. Feelings of difficulty have been shown to be greater for weaker students, while feelings of confidence are generally greater for those who are academically strong.

Is it possible to teach young students to evaluate their own learning metacognitively both during and after a task or learning activity has taken place?

Yes, it is. All of my students became better at evaluating their own learning and abilities over time. The regulatory and reflective questionnaires became easier, and their ability to appropriately assess their work in terms of strategy use, planning, monitoring, and reflecting increased. For some students, analysing their work metacognitively remained challenging, and gains were small, but they nonetheless became better at doing this over the course of the research period.

Do the self-reflection, peer- and self-assessment skills of a group of students improve over time, with guidance, practice and effort?

Most of my students' self- and peer-assessment capabilities improved over time. This was likely a result of the continued guidance and feedback from me (particularly at the start of the process), and the regularity and consistency with which we were able to implement our problem-solving and error-detection activities. One full lesson each week was used for the purposes of these tasks. This was possible because the Grade 8 curriculum includes time for alternative assessments and investigations; it is less likely that a similar programme could be carried out in the senior grades.

Implications for my own practice

It has become clear over the past three years, during which I have been completing this degree, that deliberate formative assessment is a crucial aspect of good teaching practice. While the dissertation that I completed in Part 2 confirmed that 'on-line' formative assessment is useful during teaching in guiding the ongoing pace, focus and structure of a lesson, the research conducted for this study confirmed that the implementation of formative self- and peer-assessment can positively affect the metacognition and learning experiences of my students. Prior to my investigations, I did not see formative peer- and self-assessments as truly beneficial to my students' problem-solving and general abilities in mathematics: I thought that they were not a particularly efficient or productive use of my lesson time, and assumed that my students' immaturity and lack of experience would render the experience valueless.

However, this project has given me four important take-aways: firstly, most students can and do get better at assessing themselves and peers over time (if given sufficient support and time to practice); secondly, greater levels of formative peer- and self-assessment (together with discourse arising from peer feedback, and self-reflection) can have a positive effect on the general and domain-specific metacognition of even young students (age 13 to 14); thirdly, when students are included consistently in the assessment process, while they may be resistant to it initially, they inevitable become co-facilitators of the learning that takes place in the classroom, and thus become more invested in understanding learning objectives and what needs to be done to achieve them; fourthly, my findings suggest that academically weaker students in particular may benefit both metacognitively and academically from the formative assessment process. An increase in metacognition, cognitive regulation, and awareness of learning increases the likelihood that students will improve cognitive learning and understanding, which may promote improvements in academic attainment and mathematical self-concept. It thus seems prudent to incorporate more formative self- and peer-activities into my lessons. With burgeoning curricula, even in the junior years, this will require careful planning and organisation, but can be achieved, if not quite as often as was managed for the purposes of my research. For formative assessment activities to have an impact on learning and metacognition, they need to be done regularly and consistently so that students can become more proficient. Additionally, a high level of support and guidance is initially required from students, especially when they are younger. Despite these seemingly onerous conditions, I believe that the benefits could justify the effort. I therefore plan to continue including regular (probably once every two weeks) formative self- and peer-assessment activities in my lessons going forward. Another successful feature of my intervention that I will be carrying through to my future practice is the use of a Strategy Evaluation Matrix, so that problem-solving strategies can be overtly learnt and discussed.

Further implications based on collaboration

Throughout the course of my research, I gave brief presentations of my findings to my colleagues at our staff development sessions. Although most of these are not compulsory, and therefore not well-attended, there was a group of eight teachers who regularly came to listen to me, and to share their views on my research, as well as on their own classroom practices. I came to value these sessions, and found much of their feedback useful and illuminating. There was a general increase (amongst these teachers) in the awareness of the potential benefits of formative assessment, as well an improved understanding of the variety of settings and scenarios in which it could be utilised. As a result of these sessions, two members of my own department decided to carry out regular formative tasks in their classrooms, and to introduce a more comprehensive approach to self-assessment, including the requirement of her students to reflect more formally on the deficiencies (and strengths) of their classwork. In addition, my colleague from the History department decided to utilise a post-assessment wrap for all tasks so that students would have to articulate the reasons for their academic successes and failures, and how they were going to modify their subsequent behaviours. It has been evident that my research has had a reach further than that of my own classroom, and has promoted discussions around the issues of formative assessment, which is a positive outcome for all involved.

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APPENDICES

1. Letter to headmaster
2. Letter of information to pupils
3. Examples of test sets
4. Strategy Evaluation Matrix
5. Self-regulation questionnaire
6. JrMAI questionnaire
7. IMSR questionnaire
8. Teacher's metacognitive questionnaire
9. Semi-structured whole-class discussion questions
10. Semi-structured individual interview questions
11. Raw data for students – before and after the intervention

UNIVERSITY OF OXFORD
DEPARTMENT OF EDUCATION

15 Norham Gardens, Oxford OX2 6PY
Tel: +44(0)1865 274024 Fax: +44(0)1865 274027
general.enquiries@education.ox.ac.uk www.education.ox.ac.uk

Director Professor Jo-Anne Baird

UNIVERSITY OF OXFORD

Mr Mike Thiel
St David's Marist Inanda
36 Rivonia Road, Inanda
19 November 2018

Dear Mr Thiel,

I am writing to enquire about conducting research in school this academic year. As you know, I am studying for the Master's in Learning and Teaching at Oxford University, supervised by Jenni Ingram. In my final research project "Learning about learning: An exploration into the effects of self- and peer-assessment on self-regulated learning and metacognition in the Mathematics classroom", I will investigate whether self- and peer-assessment tasks affect the ability of learners to plan, execute, and monitor their own learning.

The research will take place with a single middle-set Grade 9 mathematics class, comprising approximately 15 students. I am focusing on the potentially positive effects on students' independent learning and motivation of the process of assessing both their own, and their peers' work. I hope to establish a connection between increased levels of reflections on learning with improved metacognitive capabilities. This research will be conducted in collaboration with Liz Vernell, Suzette Richard, and Jessica Burne.

By participating in the research, the school would be contributing to a project that will deepen our understanding of mathematics learning for students with medium to low prior attainment, and so contribute towards developing ways of improving attainment for similar students in the school in the future. It will also contribute to Mathematics education more widely.

I hope to conduct this research between January and August 2019. I will be interviewing and audio-recording students while they are engaged in whole class discussions. In addition, I will be video-recording the students while they work and will be observing my collaborating colleagues while also taking notes. I will probably make photocopies of some of my students' written work.

Oxford University has strict ethical procedures on conducting ethical research, consistent with current British Educational Research Association guidelines. The University also recognises, however, that my study is a piece of practitioner research, and that schools already operate with the highest ethical standards. Therefore only <u>your</u> formal consent as headteacher is necessary, and not that of individual parents or staff. However, throughout the research, students and other teachers will be able to refuse to participate in any research activities at any time.

All participants, including students, teacher and the school, would be made anonymous in all research reports. The data collected would be kept strictly confidential, available only to my supervisor Jenni Ingram (jenni.ingram@education.ox.ac.uk) and me, and only used for academic purposes. It will be kept for as long as it has academic value.

If you are happy for me to proceed with this study, please confirm that using the attached reply form. If you have any concerns or need more information about what is involved, please contact me or my supervisor. Further, if you have any questions about this ethics process at any time, please contact the chair of the department's research ethics committee, though: research.office@education.ox.ac.uk

I look forward to hearing from you.

Yours sincerely,

Nicola Goemans

Learning about learning: An exploration into the effects of self- and peer-assessment on self-regulated learning and metacognition in the Mathematics classroom

Nicola Goemans
University of Oxford, Department of Education

St David's Marist Inanda

36 Rivonia Road, Inanda, Johannesburg

Mr Mike Thiel

☐ We do not wish to participate in this project.

☐ We would like to find out more about this project.

☑ We would like to take part in this project.

Head teacher's signature

ST DAVID'S MARIST INANDA
EXECUTIVE HEADMASTER'S
OFFICIAL
OFFICE
INANDA : SANDTON

Please return this form to me.

Thank you for your help.

INFORMATION SHEET FOR STUDENT PARTICIPANTS **21 November 2018**

Dear Student,

I am writing to enquire about obtaining consent for the purposes of conducting research in school this academic year. I am studying for the Master's in Learning and Teaching at Oxford University. In my final research project "Learning about learning: An exploration into the effects of self- and peer-assessment on self-regulated learning and metacognition in the Mathematics classroom", I will investigate whether self- and peer-assessment tasks affect the ability of learners to plan, execute, and monitor their own learning.

The research will take place within your Grade 8 mathematics class from May to August 2019. I am focusing on the potentially positive effects on students' independent learning and motivation of the process of assessing both their own, and their peers' work. I hope to establish a connection between increased levels of reflections on learning with improved metacognitive capabilities.

By participating in the research, you would be contributing to a project that will deepen our understanding of mathematics learning for students with medium prior attainment, and so contribute towards developing ways of improving attainment for similar students in the school in the future. It will also contribute to Mathematics education more widely.

For the purposes of collecting data, I will be interviewing and audio-recording students while they are engaged in whole class discussions. In addition, I will be video-recording the students while they work and will be observing students working, while also taking notes. I will probably make photocopies of some of students' written work. All data will either be anonymised or will require written consent from students to be collected. You are not in any way obliged to participate, and can at any stage refuse to take part in the research activities or tasks. The research will not in any way compromise your learning, and will be incorporated into planned lessons as much as possible. All data will be stored securely, and will be used ethically for the purposes of improving my teaching practice going forward.

Oxford University has strict ethical procedures on conducting ethical research, consistent with current British Educational Research Association guidelines. The University also recognises, however, that my study is a piece of practitioner research, and that schools already operate with the highest ethical standards.

All participants, including students, teacher and the school, would be made anonymous in all research reports. The data collected would be kept strictly confidential, available only to my supervisor Jenni Ingram (jenni.ingram@education.ox.ac.uk) and me.

If you are happy for me to proceed with this study, please complete the accompanying consent form indicating as much.

Many thanks,

Mrs Nicola Goemans

Problem-solving task 12 (to be done during class)

Code name: Pogba Jr

Mark by peer

Max could not afford to buy a Koenigsegg One:1, but he does own a Toyota Corolla and a new VW Up. The Toyota has a fuel tank capacity of 60 litres and has a Petrol engine. The VW has a fuel tank capacity of 40 litres and has a Diesel engine.

Let the cost of Diesel be x Rand per litre.

$3\frac{1}{2} + 2 + 2 = 7\frac{1}{2}/10$

marked by [illegible]

The given information is organised in the table below. The expressions represented by A, B, and C are currently unknown:

$3\frac{1}{2}/5$ 2/3

	Tank capacity (litres)	Cost of fuel (Rand / litre)	Total cost of filling the car's tank from empty (Rands)
VW (Diesel)	40	x	$40 \times x = \mathbf{40x}$
Toyota (Petrol)	60	**A**	**B**
TOTAL	**100**		**C** 1045

2/2

1) Petrol costs 75c per litre more than Diesel. Use this information to determine the expression (in terms of x) represented by **A** in the table.

✓

$A = x + 0,75$

2) Use your answer in 1, and any relevant data in the table, to formulate the expression (in terms of x) represented by **B.**

$C - 40x = B$ $B = 60(x + 0,75)$ ✓

3) Write down the simplified expression represented by **C** in the table.

✓

~~$40x + B = 6$~~ $C = 40x + 60(x + 0,75)$

4) When Max fills both cars up with fuel (from empty), it costs him a total of R1045. Use this information, as well as your expression from 10.8.3, to formulate an appropriate algebraic equation.

~~1045~~

✓

R16

5) Solve your equation to determine the actual cost of Diesel fuel (don't forget the units!).

R 10, 75

✗

Mark by me:

Accuracy $\frac{2}{5}$

Showing working $\frac{1}{3}$

Clarity $\frac{2}{2}$

$\frac{5}{10}$

4/10

Mark by self

Self-reflection questions

Code name: Pogba Jr

BEFORE you attempt the task, please read the questions carefully and answer the following questions as best as you can:

1. What kind of Maths problem is this?

~~[crossed out]~~ Problem solving

2. How well do you understand the questions?

Not very well

3. Describe how difficult or easy you think these questions will be to answer.

I think it is quite difficult

4. How much time, and what kinds of resources do you think you will need to solve these problems?

I think it would take 20-25 mins using a calculator and working with a friend

5. What kind of strategies do you think you will need to use?

Pace your work
slow down
Cheack answers
Activate knowledge
mental integration

6. How much effort do you think you will need to exert in order to solve this problem?

Maximum

3. What did you do well (what were your strengths in the task)?

I thought about what I was doing

4. What did you not do well (what were your weaknesses in the task)?

Full understanding

5. What will you do differently next time?

Take more time to understand before I put pen to paper

6. Looking back, how difficult do you think the task was?

Very! Although if we did things like this in class it would have been easier

7. Looking back, how much effort did you to exert in order to solve this problem?

Full

3/3 2/3 2/2

7/10

Mark by peer

Problem-solving task 12 (to be done during class)

Code name: CrazyRichAsian1234567890

Max could not afford to buy a Koenigsegg One:1, but he does own a Toyota Corolla and a new VW Up. The Toyota has a fuel tank capacity of 60 litres and has a Petrol engine. The VW has a fuel tank capacity of 40 litres and has a Diesel engine.

Let the cost of Diesel be x Rand per litre.

The given information is organised in the table below. The expressions represented by A, B, and C are currently unknown:

	Tank capacity (litres)	**Cost of fuel (Rand / litre)**	**Total cost of filling the car's tank from empty (Rands)**
VW (Diesel)	40	x	$40 \times x = \mathbf{40x}$
Toyota (Petrol)	60	**A**	**B**
TOTAL	**100**		**C**

1) Petrol costs 75c per litre <u>more</u> than Diesel. Use this information to determine the expression (in terms of x) represented by **A** in the table.

40x = Diesel

A = 75c + x ✓

2) Use your answer in 1, and any relevant data in the table, to formulate the expression (in terms of x) represented by **B**.

60x((x) + 75c) ✓

3) Write down the simplified expression represented by **C** in the table.

40x + B + (75 C)

∴ 40x + 60x + 75 x

= C ✓

4) When Max fills both cars up with fuel (from empty), it costs him a total of R1045. Use this information, as well as your expression from 10.8.3, to formulate an appropriate algebraic equation.

$60x + 40x + 75c = 1045$

R1045 = 100 b?

5) Solve your equation to determine the actual cost of Diesel fuel (don't forget the units!).

Diesel = R400 = 40 x 10

x = 10 ✓

Trial and error

Petrol = 10 + 0,75

= 10,75

60 x 10,75

= 645 + 400

= 1045

My mark:

Accuracy

2/5

Working/ Calculations

1/3

Clarity.

2/2

5/10

8/10 Mark by self

Self-reflection questions

Code name: CrazyRichAsian1234567890

BEFORE you attempt the task, please read the questions carefully and answer the following questions as best as you can:

1. What kind of Maths problem is this?

Algebraic question

2. How well do you understand the questions?

ok

3. Describe how difficult or easy you think these questions will be to answer.

Not to hard but not to easy

4. How much time, and what kinds of resources do you think you will need to solve these problems?

Calculator, 30-45min and working out paper and my brain, phone, textbook and asking help.

5. What kind of strategies do you think you will need to use?

Slow down, check answers, stop, read and think about information,

6. How much effort do you think you will need to exert in order to solve this problem?

Alot all of it.

3. What did you do well (what were your strengths in the task)?

Trial and error, move slowly and check over answers.

4. What did you not do well (what were your weaknesses in the task)?

Nothing

5. What will you do differently next time?

I don't know

6. Looking back, how difficult do you think the task was?

$\frac{6}{10}$

7. Looking back, how much effort did you to exert in order to solve this problem?

All of my effort.

Strategy Evaluation Matrix (SEM)

Strategy	How to use	When to use	Why to use
Slow down	Stop, read, and think about information.	When information seems especially important	To increase the focus of one's attention
Activate prior knowledge	Pause and think about what you already know, and how it might relate to what you don't know	Prior to reading, or before and during an unfamiliar task.	Makes new information easier to learn and remember.
Mental integration	Relate the main ideas. Use these to construct a theme or conclusion.	When learning complex information, or when a deeper understanding is needed.	Reduces memory load. Promotes a deeper level of understanding.
Diagrams and representations	Identify main ideas, connect them, list supporting details under main ideas, connect supporting details	When there is a lot of interrelated factual info	Helps identify main ideas, organize them into categories. Reduces memory load.
Check your answers	Pause and check your work, calculations and solutions at regular intervals.	During and after all problem-solving tasks.	Reduces risk of making errors.
Pace your work	Check time allowed and compare to time used at regular intervals.	During problem-solving tasks.	Assists in completing work and tasks within the given time.

Self-reflection questions

Code name: ____

BEFORE you attempt the task, please read the questions carefully and answer the following questions as best as you can:

1. What kind of Maths problem is this?

2. How well do you understand the questions?

3. How much <u>time</u>, and what kinds of <u>resources</u> do you think you will need to solve these problems?

4. What kind of strategies do you think you will need to use?

5. On a scale of 1 to 4, how difficult do you think this problem will be to solve.

6. On a scale from 1 to 4, how much effort do you think you will need to exert in order to solve this problem?

7. On a scale from 1 to 4, how correctly do you think you are going to solve this problem?

8. What do you think your mark out of 10 will be?

WHILE you are answering the questions, please answer the following questions as best as you can:

1. Do you have a clear understanding of what you are doing? If not, what can you do to change this?

2. How well are you checking your work as you go?

3. Are you changing your problem-solving strategies as you go, if you need to? If so, how?

AFTER you have completed the task, please answer the following questions as best as you can:

1. Predict your mark for the task out of 10.

2. How much time, and what resources, did you actually spend / use to complete the problem?

3. What strategies worked well?

4. What did you do well (what were your strengths in the task)?

5. What did you not do well (what were your weaknesses in the task)?

6. What will you do differently next time?

7. Looking back, how well do you think you did on the task (on a scale from 1 to 4)?

8. Looking back, how difficult do you think the task was (on a scale from1 to 4)?

9. Looking back, how much effort did you to exert in order to solve this problem (on a scale from 1 to 4)?

JrMAI questionnaire

1 = Never / almost never 2 = Occasionally 3 = Often 4 = All the time.

1. I know when I understand something.	1	2	3	4
2. I can make myself learn when I need to.	1	2	3	4
3. I try to use ways of studying that have worked for me before.	1	2	3	4
4. I know what the teacher expects me to learn.	1	2	3	4
5. I learn best when I already know something about the topic.	1	2	3	4
6. I draw pictures or diagrams to help me understand while learning.	1	2	3	4
7. When I am done with my schoolwork, I ask myself if I have learned what I wanted to learn.	1	2	3	4
8. I think of several ways to solve a problem and then choose the best one.	1	2	3	4
9. I think about what I need to learn before I start working.	1	2	3	4
10. I ask myself how well I am doing while I am learning something new.	1	2	3	4
11. I really pay attention to important information.	1	2	3	4
12. I learn more when I am interested in the topic.	1	2	3	4
13. I use my learning strengths to make up for my weaknesses.	1	2	3	4
14. I use different learning strategies depending on the task.	1	2	3	4
15. I occasionally check to make sure I'll get my work done on time.	1	2	3	4
16. I sometimes use learning strategies without thinking.	1	2	3	4
17. I ask myself if there was an easier way to do things after I finish a task.	1	2	3	4
18. I decide what I need to get done before I start a task.	1	2	3	4
19. I understand my intellectual strengths and weaknesses.	1	2	3	4
20. I slow down when I encounter important information.	1	2	3	4
21. I change strategies when I fail to understand something.	1	2	3	4
22. I pace myself while learning in order to have enough time.	1	2	3	4
23. I know how well I did once I finish a test.	1	2	3	4
24. I know what kind of information is most important to learn.	1	2	3	4
25. I try to break studying down into smaller steps.	1	2	3	4
26. I stop and reread when I get confused.	1	2	3	4
27. I ask myself if I have learned as much as I could have once I finish a task.	1	2	3	4
28. I ask myself how well I have accomplished my goals once I'm finished a task.	1	2	3	4
29. I ask myself if what I'm working on is related to what I already know.	1	2	3	4

IMSR questionnaire

1 = Never / almost never   2 = Occasionally   3 = Often   4 = All the time.

1. I try to understand what the problem is asking me.	1	2	3	4
2. I think of several ways to solve a problem and then choose the best one.	1	2	3	4
3. I look back at the problem to see if my answer makes sense.	1	2	3	4
4. I use different ways to memorize things.	1	2	3	4
5. I think to myself, do I understand what the problem is asking me?	1	2	3	4
6. I read the problem more than once.	1	2	3	4
7. I think about what information I need to solve this problem.	1	2	3	4
8. I use different learning strategies depending on the problem.	1	2	3	4
9. I look back to see if I did the correct procedures.	1	2	3	4
10. I think about how well I am learning when I work a difficult problem.	1	2	3	4
11. I use different ways of learning depending on the problem.	1	2	3	4
12. I go back and check my work.	1	2	3	4
13. I read the problem over and over until I understand it.	1	2	3	4
14. I check to see if my calculations are correct.	1	2	3	4
15. When it comes to learning, I can make myself learn when I need to.	1	2	3	4
16. I ask myself how well I am doing while I am learning something new.	1	2	3	4
17. I check my work all the way through the problem.	1	2	3	4
18. I identify all the important parts of the problem.	1	2	3	4
19. I try to understand the problem so I know what to do.	1	2	3	4
20. I think about all the steps as I work the problem.	1	2	3	4
21. I can make myself memorize something.	1	2	3	4
22. When it comes to learning, I know my strengths and weaknesses.	1	2	3	4
23. I pick out the steps I need to do this problem.	1	2	3	4
24. When I am done with my schoolwork, I ask myself if I learned what I wanted to learn.	1	2	3	4
25. I double-check to make sure I did it right.	1	2	3	4
26. I try to break down the problem to just the necessary information.	1	2	3	4
27. I use learning strategies without thinking.	1	2	3	4
28. When it comes to learning, I know how I learn best.	1	2	3	4
29. I ask myself if there are certain goals I want to accomplish.	1	2	3	4
30. I try more than one way to learn something r solve a problem.	1	2	3	4

Teacher questionnaire based on observation

1 = Never / almost never 2 = Occasionally 3 = Often 4 = All the time.

1. The child asks questions, looks and listens attentively to instructions and does not start solving the problem immediately without first exploring the problem.
2. The child can repeat instructions correctly and completely if asked to do so.
3. The child analyses the relevant information needed to solve problems.
4. The child rarely starts without a plan.
5. The child can differentiate relevant and irrelevant information in a task.
6. The child can answer questions about how he will be completing the task.
7. The child is able to reflect on task-relevant, previously-acquired knowledge to guide how he needs to work on a task, and what aspects of the problem he needs to be most attentive of.
8. The child connects new and previous knowledge about tasks.
9. The child is often dissatisfied with the first solution that he develops.
10. Verbal answers to questions are complete and clear.
11. The child works precisely and systematically.
12. The child works according to the plan that he developed.
13. The child changes strategies when the task demands it without prompting from the teacher.
14. After an intervention by the teacher or an independently-acquired insight, the child does not start all over but only changes what needs to be changed.
15. After finishing a task, the child checks the calculations and his answer.
16. The child attributes difficulties and failures to the correct internal and external factors.
17. The child can tell what strategies are important for solving the task, and what went well.
18. The child reflects on future problem solving by considering what he might change or d differently next time. In similar problems, previous knowledge is not forgotten.
19. The child works slowly and more carefully during difficult tasks.

Semi-structured group discussion

- How did you find the experience of assessing your own work?
- What was difficult? Why?
- What was easy? Why?
- Did assessing your own work make you think differently about how you solve maths problem?
- Do you think the score you gave yourself was fair, and does it reflect what you actually understand?
- Was assessing your own work a valuable exercise?
- What aspect of the self-assessment process, if any, would you change?
- How did you find the experience of answering the regulatory questionnaire?
- Was it useful?
- What aspect of the self-reflection process, if any, would you change?
- How did you find the experience of assessing your peer's work?
- What was difficult? Why?
- What was easy? Why?
- Did assessing your someone else's work make you think differently about how you solve maths problem?
- Do you think the score you gave your peer was fair, and does it reflect what you actually understand?
- Was assessing your own work a valuable exercise?
- What aspect of the peer-assessment process, if any, would you change?
- How easy or difficult was it to justify the numerical scores that you gave yourself and your peer?

Semi-structured interview questions

- What has been the most difficult aspect of the self-assessment process?
- What has been the easiest aspect of the self-assessment process?
- What do you think have been the main benefits of assessing your own work?
- What would you change about the process if you could?
- Do you think that you are getting better at assessing your own work over time?
- Do you think that the process of assessing your own work is improving your problem-solving abilities?
- Do you think that the process of assessing your own work is improving your understanding of when and why to apply the strategies that we have been learning about?
- What has been the most difficult aspect of the peer-assessment process?
- What has been the easiest aspect of the peer-assessment process?
- What do you think have been the main benefits of assessing your peer's work?
- What would you change about the process if you could?
- Do you think that you are getting better at assessing your peer's work over time?
- Do you think that the process of assessing your peer's work is improving your own problem-solving abilities?
- Do you think that the process of assessing your peer's work is improving your understanding of when and why to apply the strategies that we have been learning about?
- How does it feel to be assessed by a peer?
- Has being assessed by a peer been valuable? In what ways?
- What have you learnt about how to generate and then give feedback?

- Overall, has it been useful to have marking guidelines and a rubric for assessing your own and your peer's work?
- Is there any aspect of your problem-solving work that is not improving or changing? Why do you think that is?

		Before intervention						After intervention					
Student	Maths average	Self score	Peer score	Teacher score	Average JrMAI	Average IMSR	Average teacher score	Self score	Peer score	Teacher score	Average JrMAI	Average IMSR	Average teacher score
1	85	8	5	8	3.21	2.97	2.8	5	6	5	3.28	3.14	3.38
2	61	7	7	6	2.34	2.17	1.8	8	7	7	2.58	2.61	2.65
3	86	8	9	7	2.41	2.17	2.1	8	5	7	2.44	2.47	2.50
4	61	7	8	5	1.62	1.67	1.5	8	8	7	1.78	2.03	1.82
5	67	8	5	7	1.62	1.73	1.93	6	7	7	2.10	2.03	2.15
6	56	5	6	4	1.97	1.63	1.2	6	5	7	2.11	2.00	2.15
7	95	8	8	9	2.8	2.82	3.1	8	9	9	3.05	2.99	3.14
8	73	6	3	7	3.07	3.13	2.1	6	7	8	3.14	3.10	3.24
9	75	7	5	6	2.93	2.43	2.6	8	7	9	2.93	2.66	3.01
10	55	6	7	5	1.86	1.43	1.06	5	3	4	2.26	1.78	2.30
11	39	5	7	4	1.45	1.3	1.2	9	6	7	1.73	1.41	1.75
12	92	8	9	7	3.66	3.67	3.5	8	8	9	3.69	3.74	3.83
13	61	10	9	8	2.59	2.23	1.8	9	8	8	2.73	2.56	2.80
14	77	8	9	6	2.38	2.3	1.97	7	9	8	2.51	2.42	2.57
15	60	8	7	7	2.55	2.13	1.1	8	6	7	2.77	2.43	2.84