Reading to Learn Maths: A teacher professional development project in Stockholm

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Abstract
A study was conducted in 2010 in 20 Stockholm primary schools of maths teaching strategies known as Reading to Learn. The strategies involve close analysis of classroom discourse in teaching maths operations, and careful planning of teacher-class interactions based on these analyses. Classroom implementation involves repeated guided practice using these lesson plans, culminating in independent problem solving. Results of the study show that lower and middle performing students improved an average of ~20% in two months between pre and post tests. Higher performing students also improved and were better able to explain their mathematical working. Teachers also reported increased student engagement in maths, increased participation and confidence in lessons, and higher level understanding of maths concepts.

Introduction

This paper reports on the results of an evaluative study of an innovative approach to teaching the language of mathematics, known as Reading to Learn. Reading to Learn is a program designed to integrate the teaching of literacy with subject teaching in all areas of the school curriculum, including mathematics. The program originates in Australia, where it is widely used in primary, secondary and tertiary education (Koop & Rose 2008, Rose 2010, 2012), and is growing internationally, for example in South Africa (Childs 2008, Dell 2011), east Africa (African Population and Health Research Center 2011), China (Chen 2010, Liu 2010) and Latin America. Since 2009 it has been implemented in Sweden by the Multilingual Research Institute as a teacher professional learning program (Acevedo 2011). In 2010 the Institute decided to trial the Reading to Learn strategies for maths with a pilot study, and measure the outcomes in terms of students' improvements in maths learning.

Sydney School pedagogy

Reading to Learn applies research into the language of education conducted by the Sydney School of linguistic research (Martin 2000, Rose 2008, 2011). The Sydney School research program focuses particularly on the genres, or types of texts, that students need to read and write across the curriculum (Cope & Kalantzis 1993, Christie & Martin 1997, Martin & Rose 2008), together with the genres of classroom discourse through which they are learnt (Christie 2002, Martin 2006, Martin & Rose 2005, Rose & Martin 2012). One outcome of this research is the genre based writing pedagogy that is now part of the school curriculum across Australia and increasingly internationally (e.g. Indonesia). In genre writing pedagogy, teachers provide students with explicit models of the types of texts they are expected to write, and explicit guidance in doing so. A key activity in this pedagogy is Joint Construction, in which the class jointly constructs a text, with the guidance of the teacher, that follows the same structure as a model text in the target genre.

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A central principle of genre pedagogy is 'guidance through interaction in the context of shared experience'. Reading to Learn extends this principle to support students to successfully read and write across the curriculum. One aim of Reading to Learn is to 'democratise the classroom' (Rose 2005), by providing teachers with strategies to enable every student to succeed with the learning tasks expected of their grade and subject area. The fundamental tool that facilitates these strategies is close analysis of the texts that teachers want their students to read and write, and the classroom interactions through which they teach them.

Genres in maths learning

Sydney School research in the language of maths has identified four significant genres that are associated with learning the subject – procedures, explanations, definitions and problems (Rose 2012). Maths problems are often identified as a written genre unique to the subject, that many students struggle with. These so-called 'maths word problems' are intended to contextualise maths operations by relating them to students' everyday experience, but teachers often report that their wordings tend to obscure and complicate the mathematical task. Reading to Learn uses a strategy known as Detailed Reading to guide students to identify three consistent elements of these word problems, including the data provided, the type of solution required, and the operation needed to solve it. These elements are correlated with three levels of reading comprehension, i) identifying data that is literally provided in words and numbers, ii) inferring connections across the text to find the required solution, and iii) interpreting connections beyond the text to the operations needed to solve the problem.

However the aim of solving problems in maths pedagogy is primarily to practise operations (or algorithms) that have previously been demonstrated to students, and then to evaluate how well each student has learnt the operation. The pedagogic principle implicit in this activity is simply that 'practice makes perfect'. Of course it demonstrably does not do so for many students, as evaluation typically shows a wide gap between students who are most and least successful at maths. Crucially, there is no distinction in these activities between a learning task and an assessment task. Each student must practise the problems independently so that their learning can be evaluated. The question is what is being evaluated.

Before attempting these problems, it is assumed students have first learnt how to perform the relevant maths operations. Classroom observations and extensive interviews with teachers suggest that these are taught in a remarkably consistent fashion across grades and classes in the school. That is, the teacher demonstrates the operation with one or more worked examples on the class board, explaining each step orally as it is demonstrated. This widespread practice appears to be independent of any ideology or preference for traditional or progressive pedagogies. In terms of genre, the oral text provided by the teacher while demonstrating the example is a procedure. Beyond very basic algorithms such as simple addition, these oral procedures become increasingly complex as choices must be made at various points, such as whether to 'carry' or 'trade' numbers if a sum is more or less than 10. In genre theory, such complex texts are known as conditional procedures (Martin & Rose 2008, Rose 1997, Rose, McInnes & Korner 1992).

Inequality of access to maths genres

Observations of classes in Sydney School research showed another pattern that is also highly consistent (Robert Veel, pers comm 1999). Some students are able to, i) clearly follow what the teacher is saying at each step of the worked example, ii) understand the various terms that are used to denote the mathematical operation, iii) relate what is said to the mathematical process being written on the board, and iv) remember the whole procedure. This group of students may then successfully solve most of the problems through which they practise the operation, and thus benefit from the practice. Where they do make errors they can readily identify them and thus learn from their mistakes. They also tend to be able to explain how they solve each problem when asked. Other students may miss, misunderstand or misremember certain elements of the procedure, the terms being used, or relations with the worked example on the board. This group of students may then solve fewer of their independent problems correctly, and experience their mistakes more as failures than as opportunities for learning. They may thus receive less benefit from the practice that problems are intended to provide. Other students may understand and remember very little of the procedure, be unable to solve most of their problems correctly, and perceive themselves (and be perceived) as unable to 'do maths'.

Throughout a decade of Reading to Learn professional learning programs, both primary and secondary maths teachers have consistently concurred with these observations, although the proportions of students in each group vary from class to class. Teachers also comment that they spend a lot of time attempting to support struggling students, as they keep making errors and cannot articulate their workings. The issue here has to do with the emotional consequences of repeated failure, which constrains learners' capacity for processing information (van Merrienboer & Sweller 2005), rendering 'learning from mistakes' an ineffective strategy for struggling students. Our analysis of the problem is that these students have not been given sufficient guidance to perform the operation successfully, before they are required to perform it independently. The guidance that is provided by standard maths activities is sufficient for some students to perform successfully, but is inadequate for others.

The linguistic basis of learning maths concepts

Contemporary maths learning theories have an alternative explanation for variations in students' abilities to perform operations. That is that they must be able to understand the 'concept' behind it before they are able to do the operation (Devlin 2007). Maths concepts must first be learnt through a variety of activities, which may involve manual manipulation and visual perception of objects, coins, shapes or symbols. As with demonstrating worked examples, what remains unnoticed in these practices is the teacher's oral text that accompanies them.

Likewise, in order to demonstrate that they understand a mathematical concept, students are required to produce an oral text. For example, the popular Newman's Error Analysis (Newman 1983) asks students to "Tell me how you are going to work it out" and "Try doing it and as you are doing it tell me what you are thinking". In genre pedagogy, two questions we would ask here are 'what is the text that students are asked to produce', and 'where did they get it from'. The answer to the first question is an explanation of a maths concept or a procedure for working out a problem. The answer to where students get these oral texts is from their teachers. This latter contention is supported by Vygotsky's observation that,

> Any function in the child's cultural development appears twice...First it appears between people as an inter-psychological category, and then within the child as an intra-psychological category" (1981:163).

An 'inter-psychological category' is of course a concept that is exchanged through language, more specifically given verbally by a teacher to a learner. Mathematical concepts are not spontaneously generated in the learner's mind through non-verbal activities, they always involve a linguistic text. That is, mathematical concepts and operations do not exist beyond language, but are consitituted in language and are learned through language.

Maths concepts are realised linguistically as definitions. For example, one basic definition that children are expected to learn in the first years of school is addition:

> *Addition is finding the total, or sum, by combining two or more numbers.*[3]

Already this definition involves seven general, abstract or technical terms, variously related to each other in a single sentence, *addition, finding, total, sum, combining, two or more, numbers.* These terms cannot be understood by young children without concretely experiencing the actitivites they represent. This is the intuitive basis for the hands-on activities promoted in progressive maths pedagogy, without recognising the mediating role of teachers' accompanying oral texts. No amount of moving objects from one group to another can teach children how to interpret the definition of addition, without understanding the language that accompanies these activities.

In fact, the concept of addition is defined here by the operation in which it is performed, in two steps. First it is defined as a general mathematical process 'finding the total or sum', which summarises the purpose of the operation, and then as a more specific mathematical process 'by combining two or more numbers', which summarises the steps in the operation. Thus, the concept of addition is inseparable from the procedure for adding two or more numbers. The procedure is primary and the definition flows from it. In order to understand the definition, learners must first understand the procedure it refers to.

This learning sequence contradicts the accepted maxim in contemporary maths learning theory, that children must first learn the concept before they can perform the operation. This maxim derives from the progressive/constructivist objection to 'rote learning'. Rote learning is construed in this framework as meaningless repetitive behaviours without any depth of understanding. Thus traditional maths activities that were designed to memorise elements of numeracy, such as chanting times tables, have been abandoned in progressive maths pedagogy, with inevitable consequences for skills that depend on memory such as mental arithmetic.

[3] from http://www.mathsisfun.com/definitions/addition.html

The progressive/constructivist objection to repetitive practice is a philosophical position rather than an empirical conclusion based on observation. The research reported on here shows that understanding actually emerges from successful performance of operations. So-called maths concepts are actually distillations of maths operations, as shown for addition above. To understand each concept, students must first learn to do the operation. Firstly, the purpose of the operation can only be understood by experiencing its outcome. That is, the concept of 'total or sum' can only be understood through the act of adding, accompanied by a verbal procedure. Secondly, the terms used in the definitions, such as *finding, total, sum, combining, two or more numbers*, are learnt in the process of doing the activities that they refer to. The oral text that accompanies the operation mediates between the activity and the comprehension of these terms, as it presents these terms in context, in relation to the things and activities they represent. Thus if students do not understand and remember the procedure, they will not understand the terms that refer to its steps and results.

Two difficulties for maths pedagogy in recognising the linguistic basis of maths learning are that i) mathematics involves a written symbol system that appears to be independent of verbal language, and ii) the verbal texts that accompany maths operations are primarily oral and so appear not to be texts at all. In fact, the mathematical symbol system is not independent of verbal language, but is always accompanied by an oral text when it is taught and discussed. The problem for maths pedagogy is that these oral texts are invisible.

A social semiotic solution

The solution developed in Reading to Learn is not to replace current maths learning activities, but to make the oral texts that accompany them more explicit and easier for all students to acquire. To this end, we can draw on Halliday's 1993:112 observation that,

> All learning - whether learning language, learning through language, or learning about language - involves learning to understand things in more than one way… Teachers often have a powerful intuitive understanding that their pupils need to learn multimodally, using a wide variety of linguistic registers: both those of the written language, which locate them in the metaphorical world of things, and those of the spoken language, which relate what they are learning to the everyday world of doing and happening. The one foregrounds structure and stasis, the other foregrounds function and flow.

With respect to maths learning, maths operations foreground 'function and flow' for which oral procedures are well adapted, with their sequences of steps and contingencies for solving particular problems. In contrast, maths definitions foreground 'structure and stasis', as they equate one mathematical abstraction with another.

With respect to learning multimodally, modes of language vary in two dimensions, i) in relation to interaction as dialogue or monologue, which may be spoken or written, and ii) in relation to the activity construed by a text, either accompanying the activity or constituting it. Halliday refers to texts that accompany an activity as 'language-in-action', and to texts that create their own field as 'language-as-reflection'.

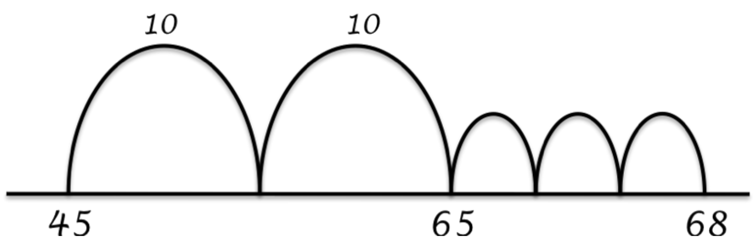
The oral procedures that accompany maths operations are examples of language-in-action. Such texts unfold contingently, referring to the activities and things that they accompany, often using reference words like *this, that, here, there*. These are characteristics of teachers' oral discourse as worked examples go up, step-by-step on the classroom board, or as children manipulate objects. One difference from everyday oral discourse is the technical terms that also pepper teachers' maths discourse.

On the other hand, maths definitions are examples of language-as-reflection. They present the dynamic function and flow of maths operations synoptically as structure and stasis. The unfolding steps of a procedure are reconstrued as a relation between a technical term, such as addition, and a distillation of the procedure as a generalised activity 'finding the total or sum'. Learning maths thus involves the complementarity between unfolding operations and the static definitions that distill them.

In terms of interaction, the teacher's text is typically an oral monologue. Students must attend to the words of the monologue and independently recognise the complex relations between what is said and the worked example that is being constructed on the board. If the operation is demonstrated more than once, the accompanying discourse may become more dialogic, as the teacher asks the class to remember what comes next. However such classroom interactions are usually between teachers and a few students who respond to their questions. It is again left to most of class to independently recognise relations between the oral discourse and the workings on the board.

By way of example, a popular early years activity for demonstrating the concept of addition is with a 'number line', as follows. First the teacher writes a sum on the board and reads it aloud, such as 23 + 45. Then a horizontal line is drawn on the board, and the largest number is written at the start of the line (45). The digits in the other number are then labelled as tens 'T' or ones 'O' (T/2 and O/3). A large arc or 'jump' is then drawn along the line for each of the 'tens', and the number 10 is written above each jump. The number of tens is then added to the large number at the end of the last jump (65). A smaller arc is then drawn along the line for each of the 'ones', and the number of ones is added to the number of tens at the end of the last jump (68). This answer is then written for the sum as 23 + 45 = 68. The number line is shown in Figure 1.

Figure 1: Number line



As simple as the diagram appears, the activity of drawing it, as recounted above, is actually quite complicated, and the teacher's oral text that accompanies it may be even more complex. Yet this is one of the simplest operations in the entire maths curriculum.
What is the solution to these twin problems of multimodal complexity and limited classroom interactivity? To manage complexity of the larning task, the general strategy applied in

Reading to Learn is known as **guided repetition**. The principle is that learners generally need modelling and guidance before they can successfully complete a learning task independently. Modelling means showing learners how to do a task, which is what teachers do with worked examples in maths. The difficulty for most students is that they are then required to independently perform associated maths problems without sufficient guided practice. Guided repetition means repeatedly guiding learners to practise the learning task, with increasing handover of control, until they are ready for independent practice. To ensure that all learners are equally engaged in the guided practice, teachers deliberately direct their interactions to specific students, once they are confident that each student can respond successfully.

A procedure for guiding maths learning

Guided repetition with maths operations begins with the teacher carefully analysing and planning exactly the words that will be spoken in each step of a worked example. These words form a detailed lesson plan. Here is an example planned by a teacher of Years 1-2, for the operation *Addition with a number line*.

1. *Read the sum.*
2. *Draw a number line.*
3. *Put the biggest number at the start of the number line.*
4. *Split the other number into tens and ones.*
5. *Make tens jumps on the number line and write 10 above each jump.*
6. *Count on in tens to find where you land.*
7. *Make ones jumps on the number line.*
8. *Count on in ones to find where you land.*
9. *Write your answer.*

There are several terms in this simple procedure that expect prior learning, including *sum, biggest number, tens, ones, count on, answer*. It assumes that children have already learnt the decimal number system, and to order numbers by their values as bigger or smaller, and to add by 'counting on' from the first number. The lesson may begin by reviewing these concepts, in relation to the first sum to be solved, that is written on the board. For example, 45 is bigger than 23 because the 'tens' number 4 is bigger than 2.

The teacher then demonstrates a worked example, as in ordinary practice, but this time using the exact planned words for each step in the procedure. The procedure is then repeated with a different example, but now the teacher starts asking the class what each step will be, and elaborates on their responses with the exact planned wordings. By the third example, the teacher can direct these questions to individual students, particularly weaker students, so that all can respond successfully and be affirmed.

This is the first step in handing over control to the students. The next step is for students to start scribing the workings on the board instead of the teacher, as the class tells them what to do at each step, with the teacher's guidance. Again the teacher ensures that weaker students are actively involved in this activity, and continually affirmed.

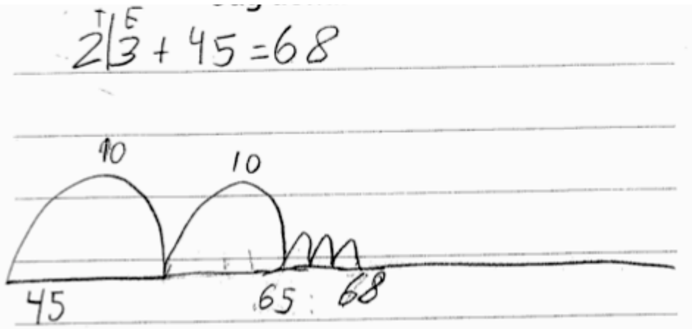
After working through two or three examples on the class board, students then practice further examples on individual boards, applying the same procedure, again with the teacher's guidance as necessary. The advantage of individual boards is that students can self-correct errors as they work and the teacher guides them. Marker pens or water-based crayons are used that can be easily erased and corrected. Unlike standard problem solving in maths workbooks, this activity is strictly a guided learning activity, and is not conflated with an assessment task.

After two or more worked examples on individual boards, the class jointly constructs a written procedure for the operation on the class board. This joint construction records the words that have been used repeatedly for each step in the procedure. Students take turns to write the procedure on the board, as the class says each step, with the teacher's guidance, and students write the text in their maths workbooks.

At this point students return to the independent tasks of standard maths practice, practising the operation they have learnt by solving problems on which they will be assessed. Now however all students get most of their problems correct, benefit from the practice, can self-correct their errors, and can explain how they solved each problem.

In sum, each repetition of the procedure involves increasing handover to the students, beginning with saying back the words the teacher has used, followed by jointly scribing examples on the board with guidance, then individual practice with guidance, until all students are ready for independent practice. Figure 2 shows an example of a Year 2 student's working, using a 'number line' to calculate an addition problem.

Figure 2: Student's working (addition with a number line)



Following the steps in the procedure, the child has

- written the sum (23 + 45 =),
- drawn a number line,
- written the biggest number 45 at the start,
- split the other number 23 into tens (T) and ones (E),
- made two tens jumps and written 10 above each jump,
- counted on in tens and written 65,
- made three ones jumps,
- counted on in ones and written 68,
- written the answer 68 in the sum at the top.

This student's success derives not only from repeated guided practice with the procedure, but also from its recontextualisation as a jointly constructed written text. Writing the procedure down has three effects. Firstly the act of joint construction gives each student more control over the words they have learnt to say and understand as the operation was performed. Secondly the act of writing and reading the joint text helps students to remember it. And thirdly, capturing the dynamic flow of the oral procedure as a written text allows the class to reflect on its structures and functions, to discuss what is done at each step and why. Not only can students use and discuss it in class, but they can take it home, so that their parents can also understand and support their maths homework.

Project methodology

The Stockholm project was conducted over three months (September to December 2010). Eleven schools[4] participated in the project with a total of 20 teachers of grades 1-6, teaching around 500 students altogether.

Participating students

The students who participated formed a most heterogeneous mix as the student populations of the participating schools were very different. At some of the schools over 90% of the students were second language learners, while students from other schools had an exclusively Swedish-speaking background. The socio-economic status of the neighbourhoods where the schools were situated also varied. These differences gave rise to numerous fruitful discussions among teachers since they had to agree to work in a similar manner with student groups that differed in many ways.

Teacher training in the strategies

To begin with the teachers attended a two day workshop where they were introduced to genre pedagogy and the Reading to Learn strategies and compared this approach with other maths learning theories. The teachers then formed groups according to the year levels of their students and started to plan the work they were going to do in their classrooms. In order to be able to compare the method and results between different schools, all teachers who taught the same year level agreed to cover the same topics with their students.

Thereafter followed a period when teachers were working in their classrooms with their selected mathematical areas. The students were given a pre test in the chosen mathematical field, using the screening tests 'ALP 1-8' (Malmer & Gudrun 2001). The ALP screening tests are commonly used in Swedish schools.

All teachers in each group implemented the same lesson plans in their classes. Data, lesson plans, video clips, student solutions, and written teacher reflections were collected. The project leaders then visited all the teachers at their respective schools to discuss the classroom implementation.

[4] Schools were Tullgårdsskolan, Husbygårdsskolan, Sturebyskolan, Snösätraskolan, Johannes skola, Vinstaskolan, Knutbyskolan, Bagarmossen/Brotorp, Skönstaholmsskolan, Hökarängsskolan, Katarina Norra skola

After a few weeks the teachers attended a second half day workshop where they discussed their progress in the classroom, decided how to proceed and planned for the next stage of parallel classroom activity. Following several more weeks of classroom implementation the teachers met for a third half day workshop. Then before the fourth and final one day workshop the students were given the ALP screening test again. In the workshop the post test results were compared to the pre test results from the beginning of the project. The outcomes of the project were discussed and the different groups summarized the work that had taken place and what the results had been. Each group then gave a short presentation on their findings to the whole group.

Data collection

The following data were collected during the project:

- Results of pre and post tests
- Video-recorded lessons
- Lesson plans for maths topics
- Students' written solutions to mathematical tasks
- Teachers' reflections on the new pedagogical strategies.

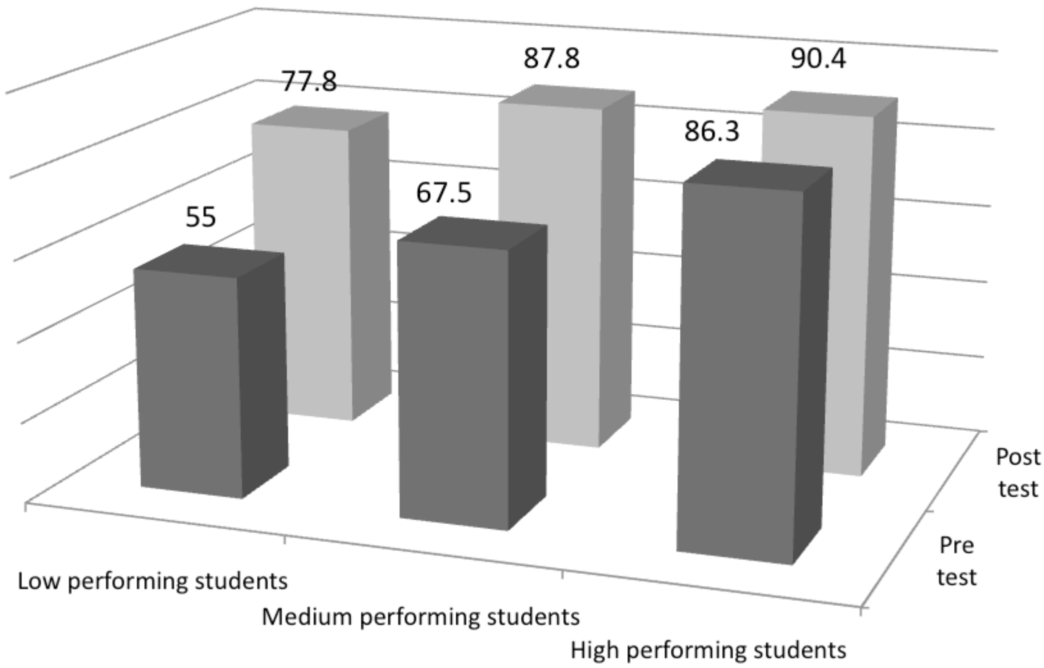
Each teacher selected six representative students for data collection: two that they perceived as high performing, two average performing and two low performing students whose test results were collected. The purpose was to measure the relative value of the strategies for each of these student groups, and the effects on the achievement gap between groups in each class. Teachers were also asked to pay attention to how the students reacted to the new teaching strategies that the teacher used.

Project outcomes

Pre and post test results

Results of pre and post tests showed improvement for all student groups, over the two terms of implementation, as shown in Figure 3. At the start of the project the low performing students attained an average 55% on pre tests, the middle groups attained an average 67.5% and the top groups an average 86.3%. In the post tests, the low-performing groups’ results increased by 22.8%, the medium-performing by 20.3%, and the high performing group by 4.1%.

Figure 3: Pre and post test results (%)



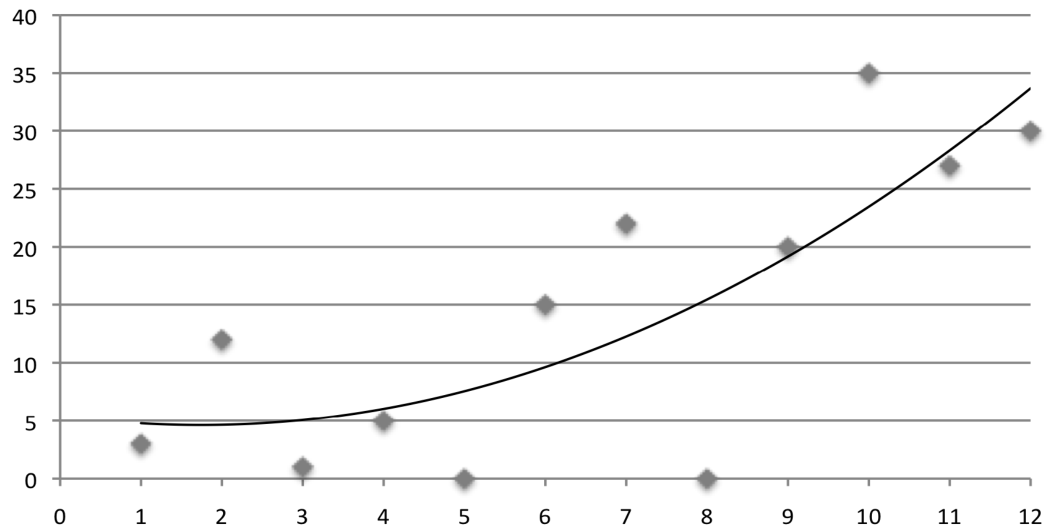
With respect to the achievement gap between students, the average difference between the low performing and high performing student groups was 31.3% in the pre test, but in the post test the difference was reduced to 12.6%, representing an 18.7% reduction in the achievement gap. The average difference between the middle and high performing groups decreased from 18.8% to just 2.6%.

Furthermore, teachers in three classes with a high proportion of second language learners emphasized that second language learners consistently showed the most dramatic improvement in performance. For example, test results showed that in one Year 3 class, second language learners made gains of up to 35%, with the lower performing students making the greatest gains, as shown in Table 1 and Figure 4.

Table 1: Pre and post test results for second language learners in Year 3

	Pre test	Post test
Student 1	90	93
Student 2	85	97
Student 3	77	78
Student 4	77	82
Student 5	73	73
Student 6	72	87
Student 7	68	90
Student 8	65	65
Student 9	48	68
Student 10	42	77
Student 11	35	62
Student 12	7	37

Figure 4: Trend data showing higher gains for lower performing students



While almost all students showed significant gains, Figure 4 shows that three students in the middle performing range (students 3, 5 and 8) apparently made little gain between the pre and post tests. These results particularly stand out against the high gains made by students 6, 7, 9, 10, 11 and 12. However it should be noted that students 3, 5 and 8 were already achieving well and have sustained that achievement level. Nevertheless the large improvements demonstrated by the other students indicates that students who make relatively little gain require closer attention.[5]

Teachers' comments on student learning

In the evaluation of the project, participating teachers reported that the pedagogy had made a great impact on student engagement. The students were engaged in the learning process at a much deeper level than they were used to. Some teachers expressed surprise that students were able to maintain focus over a much longer time than usual when the teacher used the new pedagogy. 72% of teachers felt that the pedagogy had led to increased interest in mathematics among their students. (The remaining teachers were working with students who were new to them, and so were unable to measure a change in students' attitudes.)

Several teachers commented that the gap between the high and low performing students decreased when the teacher applied the *Reading to Learn* pedagogy. One teacher said it was "obvious that the gap between the fast and the slower students decreases, the slow succeed quickly, understand mathematical problems and how to solve them." All teachers reported that the low performing students were the ones who benefited the most from the pedagogy, but that many students in the medium performing group also made great improvements. Among the high performing students, improvement was not as pronounced as in the other groups, but the teachers commented that the high performing students had

[5] This anomaly has often been observed in other whole class assessments, i.e. 2-3 students in the middle range who appear to make relatively little growth. These students' average success may mask their actual learning needs. Such assessments show teachers which students need closer attention.

learnt to explain their solutions more articulately. This applied particularly in the higher grade levels.

Teachers also considered that students' conceptual understanding had increased, particularly among second language learners. In addition, they found that students used mathematical concepts to a greater extent. They interpreted this as a consequence of the strong focus on language in the pedagogy. They also expressed surprise at how much the students appreciated repeating (all together) the verbal procedures of how a specific mathematical operation should be solved. Teachers reported that working in this new way gave students opportunities to understand and use mathematical language.

The majority of the teachers also said that the low performing students' self-confidence grew. This was noted with students who normally did not participate actively in classroom discussions about mathematics and solutions of mathematical problem, but who now attended with joy in the common conversations and common efforts to solve the mathematical details of the tasks. According to one teacher, a student had spontaneously said "At last we have a model to follow!" Others commented that "The weakest pupils feel that they are really good!" and "Those who previously thought maths was difficult thought that this was fun."

Teachers stated that all students were involved in the work when using the new approach. Many were surprised by how focused the students were during the joint efforts to solve mathematical tasks. One teacher said that students now wanted to participate by providing part of the solution to the problem and coming to the blackboard to write. "Since each student only needs to write a small part of the solution with the help of the others, it is never too difficult and all succeed." This was a new experience for many teachers who said that it was usually hard to get all the students to come up to the board and write solutions, especially the lower performing students, who often used to remain inactive in lessons.

One teacher commented that "It is good that there is a 'speed' in the methodology! They do not have time to get tired or bored!" On the other hand, some teachers mentioned that the high performing students sometimes got bored while jointly repeating the same kind of problem on the board. Teachers agreed that it would be interesting to explore what would happen to these students by raising the level further, which they thought would be possible, or if they would implement a variety of 'peel-off groups' in the classroom.[6]

Teachers' comments about their own learning

Teacher reflections on their own practice were collected both during the project and at the end. A repeated reflection was that the project would affect and change their teaching. In particular, teachers mentioned that they realized the importance of teaching explicitly and not to refer students to independent work in their maths books too quickly. They emphasized that they now understood that they probably had demonstrated new arithmetic too fast previously, with the result that many students had not understood.

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[6] Peel-off groups refers to a method of grouping that begins with the teacher working with the whole class and then allowing groups of students who require less scaffolding to move on to complete independent tasks while the teacher continues to work with others who require more support.

Teachers stated that they had not understood the importance of joint construction before, but in this project it had become clear what an impact working together has on student learning. They found that students learned much more when they have planned in detail how to explain mathematics to them and then devoted enough time to guide classes to solve tasks, with all students actively participating. Several also commented that by using this approach it is possible to increase the level of difficulty compared to what was normally possible, because of all the scaffolding that is built into the pedagogy.

In Figure 4, a Year 2 student has written down the procedure used to solve the sum in Figure 1 above.

Figure 5: Joint construction of maths procedure (student copy)

Jag ritar en tallinje.
Jag flyttar ner det
största talet. Jag delar
upp det minsta talet i
tiotal och ental. Jag lägger
till 2 tiotal och 3 ental.
Jag skriver summan som svar
på additionen. additionen är
68. Jag läser additionen.

English translation

> *I draw a number line. I write down the largest number. I divide the smallest number into tens and ones. I add 2 tens and 3 ones. I write the sum as the solution to the addition. The addition is 68. I read the addition.*

Most teachers commented that as a result of the project they have become aware of the role of language in the learning process. One teacher said that she's "now thinking in an almost totally different way than before and she has learned a new way to actively develop students' mathematical language". Examples of other reflections (translated from Swedish) included:

- *I have got a new tool to use when I teach.*
- *For the first time it feels like I'm doing something really good, real teaching.*
- *I have learned a whole new attitude and learnt to clarify the language of mathematics.*
- *The pedagogy has made me have a greater focus on language and the meaning of concepts.*
- *This way of working allowed thinking in detail about wordings, the language one uses and makes it clear not only for the students but for the teachers as well. Genre pedagogy added another dimension to a varied way – and a very effective way it is to add.*

- *The pedagogy requires more preparation by the teacher but you can "recycle" the structure for other similar lessons.*
- *You can increase the degree of difficulty when you support this thoroughly.*
- *I was negative when I saw the example video taped lessons, but when I tried it myself I was very pleasantly surprised! The students were very active and no whining that they got tired. We could go on and together solve problem after problem throughout the whole lesson. Otherwise, they tend to get bored after ten minutes. I did not have to 'beg' them to work!*

Discussion

The results of this small scale study suggest that the Reading to Learn strategies for teaching the language of maths can significantly improve the maths outcomes and engagement of students from a variety of backgrounds and achievement levels. The average improvement of middle and lower performing students of around 20% in two months is most encouraging. Although these results were achieved with a relatively small sample (~500 students in total), they are consistent with the findings of teachers in Australia (Rose 2012). They are also supported by the evaluations of teachers in the project, reported above, who consistently found that the gap between lower and higher performing students narrowed.

These results are particularly noteworthy when viewed against more typical growth rates in maths outcomes. For example, in Australia a series of large scale studies have found that there has been no significant improvement in numeracy outcomes in recent decades (NSW Auditor-General 2008, Victorian Auditor-General 2009). One large study found that numeracy outcomes have not improved since contemporary maths teaching methods were introduced in the 1960s (Leigh & Ryan 2008). One explanation for this situation, offered from the perspective of genre pedagogy, is that contemporary maths learning theories may not adequately account for the oral discourse through which maths operation and concepts are acquired by students. In particular, these theories emerged from the cognitivist stance of Piagetian psychology, which construes learning as a process internal to the individual, in contrast to social-psychological learning theories such as Vygotsky's, and social semiotic theories such as genre pedagogy. Thus, while the learning activities advocated by contemporary maths learning theory may enable some students to acquire maths concepts, a failure to explicitly analyse and plan the oral exchanges through which the concepts are taught may leave other students with inadequate support.

The genre based strategies trialled in this study do not seek to change the learning activities of contemporary maths practice. They simply make the oral discourse that accompanies these activities explicit for both teachers and students. This is achieved by the teacher carefully analysing their oral discourse, exchanging it with students through a carefully planned series of repeated activities, and the class writing it down. Aside from enabling significantly more students to achieve higher success with maths tasks, this approach has a number of associated advantages pointed out by teachers above.

Firstly it gives teachers insights into the nature of their own pedagogic discourse, not through a course of linguistics, but by bringing teachers' own unconscious knowledge about language to consciousness. The starting point for this process of 'conscientization'[7] is to name the genres of maths teaching, and so identify their structures – such as the steps in a procedure. From this point on, the analysis and planning depends on teachers' knowledge of the subject they are teaching, but the content of the subject and the language through which it is taught are no longer divorced. Teachers come to recognise that they are one and the same thing.

Secondly, it effortlessly engages all students in the activities of maths learning, including those students who are otherwise alienated and perceive themselves as unable to do maths. This is achieved by the process of 'guided repetition' which ensures that all students are always adequately supported in each learning step, experience continual success, and are continually affirmed by the teacher and class.

It is often assumed that students must be engaged in an abstract subject such as maths by continually relating it back to their everyday experience. Thus maths problems are constantly cloaked in everyday scenarios such as shopping, which for many students merely serves to obscure the mathematics. But the keys to engaging students in school learning are actually success and affirmation. Students' engagement reported by the teachers above, and their consequent growing interest in subject maths, derive from their experience of success as a result of the explicit teaching strategies of Reading to Learn. This may have implications not only for the maths classroom, making learning and teaching a pleasure, but also for students' educational and professional trajectories beyond school.

Thirdly, teachers report that it improves students' understanding of maths concepts, and makes it possible to increase the difficulty of the mathematics they study. Two of the criticisms that have been made of the pedagogy, by those who have not used it, are that it seems to involve repetitive rote learning, and that students are not learning independently, so they would not acquire a 'deep' understanding of the maths concepts. Yet practising teachers find that the opposite occurs as a result of the strategies. The explanation once again returns to the indivisibility of school knowledge and the language in which it is taught and learnt, and to the social nature of learning as an exchange between teacher and learners. That is, students deepen their understanding of mathematical concepts as they increase their control of the texts in which these concepts are encoded. This control increases through repeated exchanges between teacher and students, in which the teacher hands over more control at each step, until students are ready for independent practice. Not only can they then successfully perform the mathematical tasks expected of them, but they have the language resources to explain how they solve problems and the concepts that underlie them.

Conclusions and recommendations

The analysis of both the quantitative and qualitative data in the Stockholm pilot project indicates that the strategies developed in Reading to Learn for the teaching of mathematics can rapidly reduce the achievement gap between lower, middle and higher performing

[7] Conscientization is the English approximation of Portuguese *conscientização*, meaning 'becoming aware'. In Freirean pedagogy it is given an ideological interpretation. I have used it here to denote becoming aware of language in general.

students. Furthermore, teachers report that all students' understanding of mathematics benefits from these strategies, albeit in differing degrees, and that their engagement and interest in maths markedly improves. Accordingly, we suggest that more teachers have the opportunity to develop skills in teaching mathematics using the Reading to Learn strategies. Ideally this could be achieved using comparable professional development activities as those described for this project. In addition, further projects could explore and evaluate how this pedagogy may work in the upper grades of primary, junior and senior secondary schools and in other mathematical areas, and how quickly the levels of difficulty and abstraction may be increased as students acquire mathematical skills. One aspect of such projects may also examine how variations of group activities could be applied in the classroom to extend students' learning at different skill levels.

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