RECIPROCAL TEACHING IN MATHEMATICS

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Reciprocal Teaching in Maths: a learning strategy that builds problem solving skills and improves mathematical literacy for students.

Introduction

As stated in the June 2009 Department of Education and Early Childhood Development (DEECD) publication 'Numeracy in practice: teaching, learning and using mathematics', numeracy is best described as mathematical literacy; *"a broad set of acquired behaviours and dispositions important for effective participation in society"*. As teachers of mathematics, we were concerned that our students were under-performing when faced with written mathematical problems, i.e. that our students were not *mathematically* literate.

Although we recognize that the building of academic vocabulary as described by Marzano (2005) is critical for developing mathematical literacy, we also observed the difficulties our students encountered with understanding the *mathematical* meaning of simple words. This is a problem identified in the NSW Department of Education and Training publication 'Teaching Mathematics in Year 7' (2007), where it is stated that *"comprehension of the text is key to accessing and then addressing the mathematical question"*.

Ludwig's (2000) description of 'code breaking' is one critical disposition that learners need to possess if this comprehension is to be achieved. The two particular areas we identified student difficulty in decoding mathematical text were:

1. When the order of the information did not reflect the order of the mathematical operations (e.g. take the answer from 7 requires the calculation: 7 minus the answer).
2. Misunderstanding the prepositions used (e.g. 12 is divided by 3, compared to; what number, divided by 12 is 3).

Literacy education in Australia has been shaped over the years by many influences (Alvermann, 2001; Harvey & Goudvis, 2000; Ludwig, 2000). Many publications and State Governments promote their own views on what constitutes effective literacy education, and the different competences attributed to each theory. Whilst debate continues on which literacy program is more effective, it is widely agreed that literacy is an essential component of education.

In response to an investigation in 1999 by the Department of Education, Training and Youth Affairs, into the literacy levels of all children in mainstream education in years 5 – 9, the Middle Years Literacy Program was introduced. This program was designed to improve the literacy outcomes for all students by developing teacher understanding of both language acquisition and classroom practice. With the assistance of the Middle Years Literacy Program and a school appointed literacy coordinator, a number of well established strategies were introduced to Government schools (MCCETYA, 2000). One such strategy was Reciprocal Teaching.

Reciprocal Teaching

Reciprocal Teaching was first described by Palincsar in her dissertation thesis in 1982 (Palincsar and Brown 1984). The procedure was further refined (Palincsar and Brown, 1984) and has since been described by many in relation to the teaching of literacy (DEECD2008 & 2007; DET, 2006). Reciprocal Teaching is an instructional procedure that was designed to improve reading comprehension. This is achieved by encouraging a group of students to work together to construct meaning and build understanding from a range of texts. Reciprocal Teaching, as described by Palincsar and Brown, has four stages; predicting, clarifying, questioning and summarising (DEECD, 2008).

Predicting

During the prediction stage the learner must anticipate what happens next. The prediction is based on prior knowledge, the structure of the text, headings, content and illustrations. The prediction stage also provides learners with a motivation to continue reading, as they often wish to determine if their initial prediction was correct. Prediction encourages learners to think ahead (DEECD 2008 & 2007; DET, 2006).

Clarifying

As part of the clarification stage learners are encouraged to identify areas of difficulty, such as unfamiliar vocabulary, unfamiliar text structure or new and difficult concepts. These difficulties contribute to students losing track of the meaning of the text and therefore

cannot access what it contains. During the clarification stage learners are encouraged to fix areas of deficit and then re-read the text to restore meaning.

The clarification stage is particularly useful for learners who have a history of problems with comprehension, as these learners often have difficulty in making the text flow and thus lose meaning (DEECD 2008 & 2007; DET, 2006).

Questioning

The questioning stage provides the learner with an opportunity to explore the meaning of the text. The learner is encouraged to identify the key components of the text and generate questions. Before a learner can successfully generate a question, they must first find the relevant information within the text. This process ensures they become more actively involved by designing and answering questions rather than just responding to the teachers questions. The question stage also helps the learner to monitor their own comprehension; it is a means of self-checking. This stage also reinforces summarising strategies (DEECD 2008 & 2007; DET, 2006).

Summarising

The summarising stage encourages the learner to identify and integrate important information presented within the text. Summarising can happen over a sentence, a paragraph or the whole text (DEECD 2008 & 2007; DET, 2006).

The Problem – Mathematics

As previously stated, the experience in our teaching practice has shown that many students have difficulty solving word-based mathematical problems. These same students, conversely, are able to solve an equivalent numerical problem, including selection of the correct mathematical operations and identification of the processes involved. As mathematical literacy deficiency (Marzano & Pickering, 2005; Booker, Bond, Sparrow and Swan 2004; Ludwig, 2000) is a major contributor to poor mathematical performance, the logical intervention for our students is to target their comprehension of written mathematical problems to improve learning outcomes.

An action research project was designed in February of 2009, to test a Reciprocal Teaching model for mathematics. As the current model, developed by Palincsar and Brown (1984), is based on improving literacy in English based subjects, we adapted the current strategy for better application to the mathematics stream. Two Year 7 classes, controlled for ability, gender and behaviour, were presented with identical mathematical problems. One class used our Reciprocal teaching model, and the other used any problem solving strategy of their choice.

Why Reciprocal Teaching?

Reciprocal Teaching is a well structured strategy that increases student comprehension (DEECD 2008 & 2007), it also improves understanding of complex tasks and thus helps students to gain confidence and motivation to read (DET, 2006). Secondly, Alvermann (2001) suggests that an adolescent's perception of how competent they are as readers affects how motivated they are to learn in subject area such as mathematics. Alvermann goes on to argue that engaging students in small groups and treating text as a tool for learning is preferable to treating text only as a repository of information to be memorised. Thirdly, our students are familiar with the Reciprocal Teaching process and have experienced significant success (whole school improvement of reading age by an average of 2 years in 2007 and 2008) in our literacy program, SUNLIT. Because of this, we believed that the students would "buy in" to the Reciprocal Teaching process.

Reciprocal Teaching for Mathematics

Our Reciprocal Teaching for Mathematics strategy, although based on the model proposed by Palincsar and Brown, has a number of key adjustments. This revised Reciprocal Teaching strategy also has four stages; predicting, clarifying, solving and summarising.

Predicting

During the prediction stage the learner is required to predict the type of mathematical questions they are being asked, what type of mathematical operations they may be required to use and what their answer might look like. Once again there is a heavy emphasis on using prior knowledge, the structure of the text, headings, content and illustrations or diagrams.

Clarifying

During the clarification stage the learner is required to list three groups of information. The first list contains words they are unfamiliar with, the second states all the facts they know, i.e. generally statements or values from the mathematical problem (Gifford & Gore, 2008). The last list requires a higher order of mathematical thinking and asks the students to compile a list of the information they have yet to determine in order to successfully solve the problem.

As part of the clarification stage, learners are encouraged to work as part of a group. Group work provides an opportunity for students to talk and socially interact with their peers; it helps them to construct meaning and promotes learning and literacy (MCCETYA, 2002;

Alvermann, 2001). Once the learners have clarified all areas of deficit, they are encouraged to re-read the text to restore meaning (Booker *et al,* 2004; Harvey & Goudvis, 2000).

Solving

During the solving stage learners actually solve the problem. Learners are provided with a number of problem solving options, though at no stage are the students directed to a specific problem solving strategy. This empowers the student to develop a solution which is pertinent to them as learners. (Booker *et al,* 2004). During the solving stage, the learners are required to represent their working out and their solution using pictures or diagrams, numbers and words.

Summarising

The summarising stage is completed by the individual as a self-reflection. This stage requires learners to evaluate how they contributed to the group task. The learner is also required to reflect on the strategies they have selected and to evaluate how they would refine the process if presented with a similar problem. The learner is also asked to justify their answer. To further enhance the mathematical understanding of all the students in the class, at the conclusion of each lesson we discuss and reflect on the mathematical solutions that have been offered by each group (Siemon & Virgona, 2007).

The final component of the Reciprocal Teaching for Mathematics strategy is recording. Throughout the entire process learners are required to keep a written record of what they have completed under each of the four headings. This is the main area where our model deviates from the Reciprocal teaching model used in literacy. The record keeping integrates reading and writing and continuously reinforces the importance of both. Recording is also thought to lead to improved comprehension and retention of subject area content (Booker *et al,* 2004), and it provides an opportunity for corrective feedback which is necessary to help students develop (Siemon & Virgona, 2007).

Discussion

Sunshine College is a multi-campus Government secondary school located in the Western Metropolitan region of Melbourne. It was formed in 1991, through the reorganisation of six schools. It is positioned across four sites and is made up of three junior and one senior campus. On the three junior sites all students receive four fifty-minute periods of mathematical instruction per week.

Since March 2009, both Year 7 classes have received one period of Reciprocal Teaching of Mathematics per week. During the reciprocal teaching lessons, classes were split into two equally competent groups (based on On Demand data, Learning Assessment Framework (LAF) from the Scaffolding Numeracy Middle Years (SNMY) levels and Victoran Essential Learning (VELS) outcomes). One group was taught, using the Reciprocal Teaching for Mathematics strategy while the other group was not. Each group was provided with the same question and their answers and responses were collected and compared using both our marking rubric and anecdotal evidence. Throughout this time, a number of observations were made which both informed and refined the Reciprocal Teaching for Mathematics process.

Both classes of students were placed into smaller groups of no more than three students. Each student was supplied with a piece of paper to record their work. All groups had equal access to the maths task room and any teacher assistance they required. The only difference between the groups was that one group was required to use the Reciprocal Teaching for Mathematics process, while the other group could use any problem solving strategies they wished.

Observations

Throughout our period of research we noted that the students in the non-reciprocal teaching group complete each question quicker than the reciprocal teaching group. In fact, on one particular day the non-reciprocal group completed four questions in a 30 minute period. This is considerably faster than the students in the reciprocal teaching group, who were able to complete only one or two questions. However, when reviewing the students' responses, less than one-third of the non-reciprocal teaching group correctly solved their questions, whereas three-quarters of the reciprocal teaching group had correct responses.

Interestingly, all students strongly believed they had submitted the correct response. In fact, the non-reciprocal teaching group were so confident most displayed minimal working out or checking of answers. At no stage did they provide evidence to suggest they had either reflected upon what they had achieved or testified to the validity of their answers.

When students from the non-reciprocal teaching group were questioned as to how they generated an answer they had minimal responses to offer (except for two students). Most replied 'it was easy' or 'we just doubled it' or 'added numbers together'. When the reciprocal teaching group were questioned most students were able to explain, even if in little detail, what they had done and how they had come up with the answer.

On another occasion both groups of students were given a question which involved determining the different views of a collection of blocks. Initially the students in the non-reciprocal teaching group appeared to use no strategy, with many just randomly manipulating the numbers in the question. This continued until one group asked for a set

of blocks from the maths task centre. Once one group began using the blocks two of the remaining three groups also requested a set of blocks. The three groups who used the blocks correctly answered the question; the group who did not use the blocks was unsuccessful. On reflection this may demonstrate how success may be achieved by using concrete materials or manipulatives to visualising a solution. This may also explain why students, who are encouraged to use pictures, as in the reciprocal teaching group, are able to more accurately visualize the problem. This appears to lead to better comprehension and more successful outcomes as compared to students in the non-reciprocal teaching group.

The students in the reciprocal teaching group write significantly more when compared with the non-reciprocal teaching group. This we believe is primarily because the reciprocal teaching group has been supplied with a structure. This structure requires students to address the question or text a minimum of four times, whereas the non-reciprocal teaching group tend to read the question just once and then answer it. Students in the reciprocal teaching group are continuously obliged to re-address the question a number of times before attempting a solution.

On one occasion a student was suspected of copying the work of two other students in his group. As he was a member of the non-reciprocal teaching group, and his recording was minimal, it was more difficult to determine from his work if the ideas or solutions he demonstrated were his own. However, if he had been in the reciprocal teaching group, significantly more of his work would have recorded. Reciprocal Teaching for Mathematics appears to be a more transparent system in this regard.

Where to now?

Over the past three months we believe the introduction of the Reciprocal Teaching for Mathematic strategy has improved the way students in Year 7 approach written based mathematical problems. Those using the Reciprocal Teaching for Mathematics strategy appear to be more engaged and more groups were able to successful solve the problem. It is also possible with this process to establish how the mathematical literacy of each student is developing using analysis of the clarifying statements that the learner generates.

As the student becomes more literate, the clarifying questions have less of a literacy bias and become more mathematical, i.e. as a student's comprehension increases they are more able to identify the mathematics which is required for the solution.

Due to the perceived success of this trial, Reciprocal Teaching for Mathematics was introduced into all Year 8 and 9 classes during the second semester of 2009.

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