DOCUMENT RESUME

ED 415 244		TM 027 906
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TITLE	Beyond the Basics: Assessing Students' Metacognition.	
PUB DATE	1997-11-00	
NOTE	24p.; Paper presented at the Annual Meeting of the Hong Kong Educational Research Association (14th, Hong Kong, November 1997).	
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)	
EDRS PRICE	MF01/PC01 Plus Postage.	
DESCRIPTORS	Definitions; *Educational Assessment; *Elementary School Students; Evaluation Methods; Grade 6; Intermediate Grades; Interviews; *Mathematics Education; *Metacognition; Pilot Projects; *Problem Solving; *Student Evaluation	
IDENTIFIERS	Open Ended Questions; *Self Report Measures	

ABSTRACT

This paper is concerned with the assessability of metacognition, asserting that unless metacognition can be assessed, then it will never be considered a legitimate part of curriculum. The paper focuses on a pilot study conducted with grade-six students in the curriculum domain of mathematics. It reports the results of student questionnaires and interviews that asked students to describe what they did when they solved open-ended mathematics questions. Questionnaires were completed by 15 sixth graders from 2 schools, and 5 students participated in interviews. The pilot study was planned to highlight key aspects of students' metacognitive thinking, but it also raised important methodological questions about the validity of assessments of student thinking. Existing definitions of metacognition appear to be imprecise and difficult to interpret in operational terms. However, self-reporting appears to be a valid method for researching metacognition when used in conjunction with other reliable methods and checking procedures. An appendix presents a table of metacognitive behavior. (Contains 2 figures, 1 table, and 68 references.) (Author/SLD)

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BEYOND THE BASICS: ASSESSING STUDENTS' METACOGNITION

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Paper Presented at the 14th Annual Hong Kong Educational Research Association Conference. Hong Kong. November, 1997.

Abstract

The importance of metacognition for student learning has been widely acknowledged (Anderson and Walker, 1991, Biggs, 1987, Birenbaum, 1996, Brown and De Loache, 1983, Pintrich, and De Groot, 1990 Wilson and Wing Jan, 1993, Wilson and Wing Jan, in press). But the practicalities associated with teaching for metacognition and monitoring metacognition are not clear. This paper is concerned about the assessability of metacognition. It is asserted that unless metacognition can be assessed then it will never be considered a legitimate part of curriculum.

This paper focuses on the results of a pilot study that has been conducted with upper primary students in the curriculum domain of mathematics. It reports the results of student questionnaires and interviews which asked students to describe what they did when they solved open ended mathematics problems. The pilot study was planned to highlight key aspects of students' metacognitive thinking but it also raised important methodological questions about the validity of assessments of student thinking.

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Introduction

Many curriculum documents in Australia promote the importance of metacognition, for example, The Australian National Statement on Mathematics, Australian Educational Council, (1991) and Ministry of Education, (1989). Many teachers and researchers believe that students' thinking about their own thinking and learning will improve the educational outcomes of students (Anderson and Walker, 1991, Biggs, 1987, Perry, 1989, Stacey, 1990, Wittrock, 1986). Students who exhibit advanced skills in a content area are assumed to have well developed metacognitive skills in that area (Royer, Cisero and Carlo, 1993). But there is much confusion about the meaning of metacognition. The term 'metacognition' has not been clearly defined, little teacher reference material about metacognition has been written and even less assessment material is available to monitor metacognition. With little teacher support, an 'overcrowded curriculum' (Pigdon and Woolley, Eds, 1992) and a move to test the basics, metacognition may be seen as unachievable as a curricula goal.

Projects such as PEEL (Baird and Northfield, Eds, 1992) embody the notion that metacognition is important and that it can be taught. Clarke (1988) argues that assessment should monitor the development of the attributes and capabilities that we value. This paper asserts that if metacognition can be taught it should be assessed. Assessment of any aspect of the curriculum increases the likelihood of it being taught. If metacognition is desirable then tasks which monitor metacognition would be worthwhile identifying. If metacognition cannot be assessed then it will remain attractive at a theoretical level only. It is sometimes argued that assessment should not lead curriculum (Royer, Cisero and Carlo, 1993) but in reality this is often how change is instigated. This is particularly true of high stakes assessment (Clarke and Stephens, 1996).

Some writers make the link between assessment and metacognition by suggesting that student self-assessment, where students are involved in the process of making judgements about their own learning (Boud, 1991), is a means to develop metacognition. As an instructional tool self-assessment could be used to develop metacognitive skills. As an assessment tool self-assessment could be used to assess cognition. The assessment of metacognition could lie in the judgements about the effectiveness of student use of the self-assessment medium or self-assessment items could ask students to reflect on their own thinking.

The development of 'teacher friendly' assessment materials in the area of metacognition would improve the likelihood of metacognition being seen as important, viable and basic to student development. This study was the initial stage of a larger, overarching project which aims to identify strategies for assessing metacognition. This paper reports on the results of the pilot study. It highlights methodological questions about instruments used to assess student metacognitive thinking.

Defining assessment

The terms assessment and evaluation are used differently by different people and often interchangeably. Sims (1992) reports that the effect of the terms assessment, evaluation and measurement being used synonymously has caused confusion and in some cases mistrust and hostility.

The Victorian Ministry of Education in 1988 distinguished between assessment and evaluation. They defined assessment as a 'process concerned with gathering information about students' competencies where the focus is not only what has been achieved by students but also how they have gone about learning.' (1988 : 96) They define evaluation as the process 'where judgments are made about the worth of educational programs.' (1988 : 96) Wilson also explores the connection between these two processes: 'The term assessment is given to the process of collecting and analysing information about student performance....Evaluation depends on assessment because it makes use of this collected information to make informed decisions about future activities and programs.'(1992 : 110-111). Later, Wilson and Fehring (1995) use the term evaluation to denote the making of judgments about students' work and the effectiveness of teaching and learning methods, programs and resources.

The term assessment will be used throughout this paper to refer to the *collection of information about students' learning*.

Defining metacognition

Despite a growing interest in the concept of metacognition over the last twenty years and attempts to define reflective and metacognitive thinking, a lack of clarity has existed (Brown, 1987, Munroe, 1993, Weinert, 1987). Metacognition is defined below after a brief review of the literature.

The literature associated with metacognition dates back to Dewey in 1933. Although he didn't use the word metacognition, Dewey spoke of 'reflective self-awareness',-the importance of active, persistent and careful consideration of beliefs and knowledge. Flavell (1976) was the first to use the term 'metacognition', which refers to the individual's awareness, consideration and control of his or her own cognitive processes and strategies. Since then there have been a variety of meanings given to the term.

Perry (1989) summarised theorists' attempts to classify and describe metacognition. She refers to Brown and De Loache (1978) who speak of knowing about knowing, Kontos (1983) who describes knowing and conscious control of cognitive processes, Brown, Bransford, Ferrara, and Campione, (1983) who state that knowledge about cognition and self-regulation of cognition are equally important twin aspects of metacognition, and Paris, Saarnio, and Cross, (1984) who simply define metacognition as what you know about how you know. Brown defined metacognition simply as referring to 'one's knowledge and control of one's own cognitive system.' (1987 : 67). Schraw and Dennison (1994) include a reflective component in their definition of metacognition: 'Metacognition refers to the ability to reflect upon, understand and control one's learning.' (1994: 460)

Garofalo and Lester (1984) claim the confusion over the term metacognition is due to metacognition having two separate but related aspects: knowledge and beliefs about cognition and the regulation and control of cognitive actions. They suggest that it is difficult to distinguish cognition from metacognition. Garofalo and Lester explain the difference and relationship between them by simplifying cognition as 'involved in doing, whereas metacognition is involved in choosing and planning what to do and monitoring what is being done.' (1984 : 163) Metacognition is knowing when, where and how to use knowledge and beliefs.

Brown (1987) and Schoenfeld (1990) agree that an understanding of the term metacognition is difficult because it is used to refer to two distinct areas of research: knowledge about cognition and regulation of cognition. The concept of metacognition is difficult to use because it has 'multiple and almost disjoint meanings, for example, knowledge about one's thought processes and self-regulation during problem solving'. (Schoenfeld, 1990:1)

Weinert (1987) suggests that the problems of definition are made apparent when attempting to apply the term to specific instances. Questions are raised about whether metacognitive knowledge must be utilised, whether it must be conscious and verbalisable and whether it must be generalized across situations. The problem of definition has implications for methodology because without a clear definition the investigation cannot proceed. A definition provides the parameters for research and a means to analyse the results of the investigation.

My synthesis of the preceding literature overview takes the form of the following definition: Metacognition refers to the *awareness individuals have of their own thinking and their ability to evaluate and regulate their own thinking.*

The model below represents metacognition as it is employed in this paper. It is used as a framework. Borkowski and Muthukrishna (1992) stress the importance of developing working models for metacognition in curriculum delivery: 'A working model provides a scheme for organising knowledge, a framework in which to incorporate new information, and a springboard for launching future actions.' (1992 : 480). The model shows that there are three functions of metacognition which include: Awareness, Evaluation and Regulation of one's own thinking. Awareness and Evaluation are components of the thinking activity I will call Monitoring. Reflection is the mediating process whereby Awareness may become Evaluation and Evaluation may be transformed into Regulation of the thinking processes. (See Figure 1)

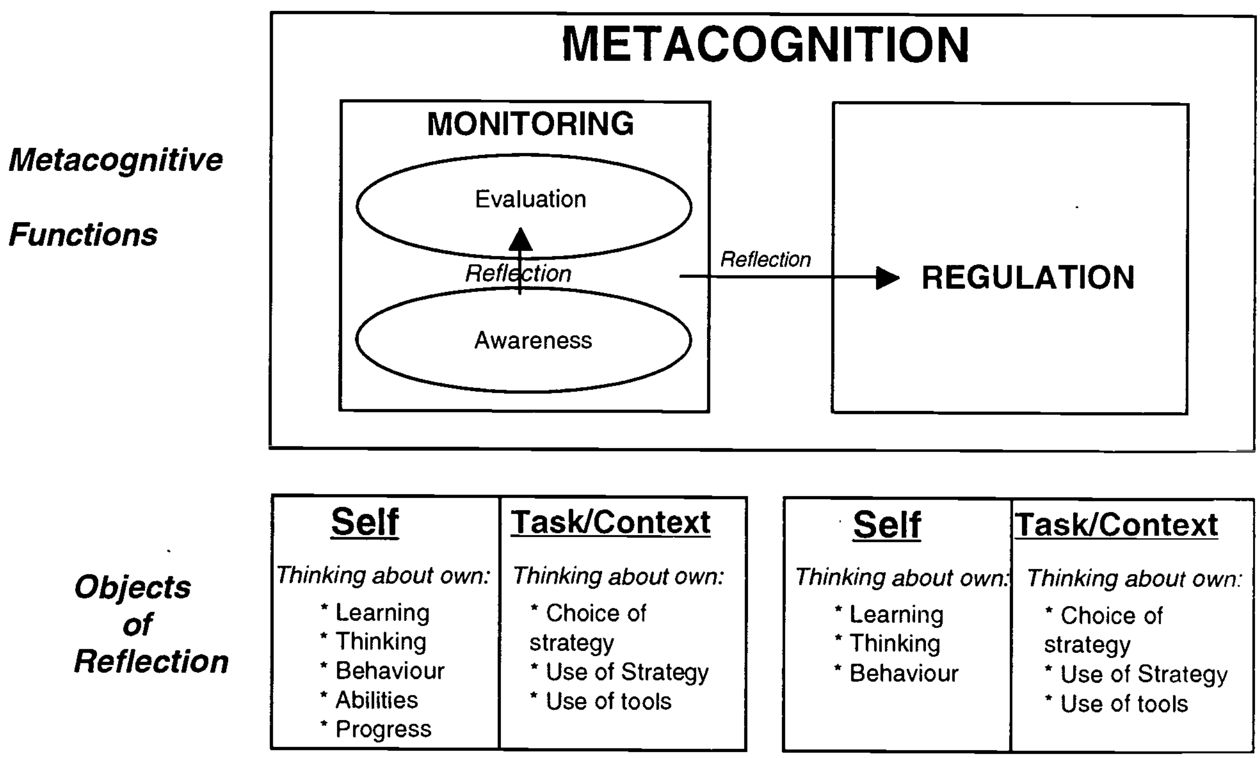

Figure 1. Model of Metacognition

The three functions of metacognition are clarified below:

Metacognitive Awareness relates to an individual's awareness of where they are in the learning process, their knowledge about personal learning strategies and what needs to be done (Baird, 1991).

Metacognitive Evaluation refers to judgements made regarding one's thinking capacities and limitations as these are employed in a particular situation or as self-attributes. For example, individuals could be making a judgement on the effectiveness of their thinking and strategy choice.

Metacognitive Regulation occurs when individuals modify their thinking. They make use of their ***metacognitive skills*** to control their knowledge and thinking. They reflect on their knowledge about self and strategies (how and why they may use particular strategies). Schraw and Dennison (1994) refer to these ways of thinking about thinking as declarative, procedural and conditional knowledge. These include abilities to plan, self-correct, set goals and the effective use of one's own cognitive resources (Brown, 1978, Scardamalia, Bereiter and Steinbach, 1985). Metacognitive skills are needed to make use of knowledge in the process of regulating thinking.

Learners who are metacognitively aware- who have developed metacognitive skills and are able to access their metacognitive knowledge- have the capacity to monitor and direct their own learning. Regulation (which is sometimes referred to as control) is associated with active reflection on one's own thinking and involves deliberate decision making about what to do and how to act. In other words, when the learner monitors their thinking, makes a judgement about their own thinking or consciously decides to act upon their reflections they have been metacognitive.

It is acknowledged that metacognition occurs within a context (for example, a classroom) and that other aspects related to the context of learning such as students' prior knowledge, abilities, preferred ways of learning, values and expectations (Biggs, 1993) and volition (Corno, 1993) affect the nature of learning and thinking. These have not been discounted as important because they have not been represented on the model (Figure 1).

Metacognition and mathematics

In research studies investigating mathematics understanding and metacognitive decision making, Goos (1993, 1994, 1995) makes claims about metacognitive aspects of mathematical thinking: 'Metacognitive processes are considered to be an important factor influencing problem solving performance.' (Goos, 1993 : 1). Schoenfeld, (1987), Venezky and Bregar, (1990) agree that the ability to monitor one's own learning increases the effectiveness of problem solving.

Stacey claims that: 'Good problem solvers tend to show more meta-cognitive knowledge. ie an awareness of the processes of learning and mathematics.'(1990:6) Research in the field of mathematics and metacognition has reported that students having difficulties with mathematics do not use a range of cognitive or metacognitive strategies, Cardelle-Elewar (1992) and Munro (1993). These suggestions of a link between metacognition and effective problem solving in mathematics strengthen the case for investigating the assessment of metacognition.

Methodology

In order to monitor metacognition, specific data collection methods and checking procedures were chosen to increase the trustworthiness and reliability of the study. In summary this involved: the use of questionnaires (including an inventory for student self-reporting) and interviews with grade 6 students in 2 different schools and the use of a questionnaire with one teacher.

The analysis undertaken in this paper relies on inferences made by the researcher about the type of metacognitive thinking. The researcher's interpretation should model the metacognitive activity of the student. In order for the reader to trust the analysis of the data, the researcher must make the analysis methods explicit. In this study the metacognitive behaviors in the inventory (part of the student questionnaire) used to gauge levels and make judgements about metacognitive performance have been based on behaviors specified on the table on metacognitive behavior. This metacognitive behavior table has been based on my definition of metacognition and devised after a thorough examination of the literature (See appendix 1). Each item has been constructed by adapting the assertions of other authors about metacognitive behavior. The items have been listed in the results section.

Questions of legitimacy

There are many objections raised about the legitimacy of researching and assessing metacognition. For example: Metacognition cannot be assessed because:

1. An agreement on a definition has not been achieved. Reseachers cannot assess what you cannot define.
2. Reseachers can only assess the consequences of metacognition. Teachers may interpret outcomes as indicative of thinking but performance doesn't indicate metacognition only cognition.
3. Self-reporting has commonly been used in research about metacognition. But the validity of self-reporting is questionable (Nisbett and Wilson, 1977, Nuthall and Alton-Lee, 1995). Thinkers may not be conscious of their own thinking and they may not be able to accurately describe it.

These objections are expanded below and addressed in this paper.

Garofalo and Lester (1984) suggest there are at least three reasons why the link between metacognition and mathematics performance has not been studied systematically. Firstly, they claim, mental activity is difficult to observe and analyse. If, as some psychologists suggest, people have no direct access to their mental processes, self-reports (a technique often associated with metacognitive research) should be considered highly questionable. Secondly, when self-reports are used while subjects perform a task this may affect cognitive processes. The methodology may create the effect it seeks to study: self-reporting may stimulate metacognition rather than provide data on cognition and metacognition. It is interesting, given the connection made between assessment and metacognition in this study, that Clarke (1992 and 1996) also alerts us to the influence assessment has on student mathematical behavior and performance. He reports that it distorts the behavior it was intended to monitor. Indeed most forms of research have the potential to distort behavior.

Webb (1966) also raised the issue about affecting data during the use of some techniques (such as questionnaires and interviews). He claimed they intrude into the natural setting and may, in the process of measuring, create and reconstruct atypical responses to those which may otherwise have occurred. The same may be argued for many other techniques used in a range of research. Research into metacognition compounds this problem by employing as the agency for data collection the very process about which data is sought. Thirdly, Garofalo and Lester (1984) assert the problem of terminology clarification continues to exist. As long as metacognition as a phenomena remains ill-defined, Garofalo and Lester claim research in the area will attract little attention. Although the literature search results would agree with the lack of shared meaning for the term metacognition, the amount of research conducted in the field suggests that the issue has created intrigue and engaged many researchers, particularly since 1984.

The validity of verbal methods of data collection in the area of thinking processes have been questioned. Increased linguistic abilities are sometimes given as a reason as to why student metacognitive awareness and control is reported to increase with age. But oral articulation of elements of thinking may not represent actual thinking processes. Nisbett and Wilson (1977) argue that students are unable to give accurate explanations for their behavior. Thorpe and Satterly (1990) share a concern for the adequacy of measures of metacognition. They suggest that when measures rely on self-reporting they are also heavily dependent upon linguistic skills and therefore results may merely reflect language development rather than metacognitive change. Articulation of elements of thinking may not represent actual thinking processes.

Thorpe and Satterly (1990) also suggest that metacognition is specific to the task from which it is derived and question the transfer of such skills. The implication of this statement is the need for a thorough and detailed analysis of the use of metacognition in different contexts to ensure that metacognition exists in more than one situation or with different types of problems. The use of different tasks is used in this study to cross check information.

Choice of methods

The methods used in this study have been carefully chosen after consideration of the following:
- questions of legitimacy in assessing metacognition,
- the effects of the various data collection techniques on metacognitive behavior and the
- suitability of each method when used with children.

A short questionnaire which included open-ended questions, an inventory of metacognitive behaviors, together with an interview to clarify responses formed the basis of student data collection with regards to metacognitive thinking.

Interviews

The principle advantage of the interview is that the collection of data is through direct verbal interaction. This allows for probing if more complex responses are needed. The procedure allows individual responses to be followed up. Details about inconsistencies or questions of the interviewer can be collected which are not possible through questionnaires. The data collected was compared to the teacher's reported problem solving instructions.

Interviewing procedures are based on the assumption that 'the person interviewed has insight into the cause of her behavior.' Cohen and Manion (1994 : 283). Cohen and Manion (1994) also suggest that this is rarely achieved. I believe the difficulty of respondents' describing their own thinking is heightened when dealing with children and when trying to monitor cognition or metacognition. Where written responses are difficult, interviews provide a forum for verbal responses.

But the flexibility and personal nature of the interview also allows for subjectivity and bias. Borg and Gall (1989) believe that direct interaction through the interview process is both the major advantage and disadvantage of interviews. Cohen and Manion (1994) support the idea that one way to validate the interview is to compare it with another measure. If the two measures agree validity is assumed. They call this comparison 'convergent validity.' (1994: 281) The use of student questionnaires and teacher interviews were used in this study.

It was decided that 15-20 minutes was optimal to maintain concentration of children in interviews. Pines, Novak, Possner, Van Kirk, (1978) suggest that time beyond this limit can produce: ' adverse results in both the quality and validity of the data, and in the affective response of the subject.' (1978 : 22)

Questionnaires

Questionnaires are assumed to be valid because they can be anonymous and are therefore likely to encourage honesty. It is recognised that the use of questionnaires is not a simple matter when dealing with children. The difficulty of misinterpretation and misunderstanding of questions was considered and a trialling of the questions was conducted with a similar sample of children at another site before the pilot study. It is acknowledged that because this study involved children, some with limited written literacy skills, the questions needed to be simple. The questions were trialled to increase the probability of age appropriateness and I was present during the implementation of all questionnaires to clarify questions.

The disadvantages of questionnaires were not a major problem in this study. Interviews were conducted immediately after the implementation of the questionnaire. Issues which arose from the questionnaires were able to be discussed where necessary.

Self-reporting

Self-reporting is often associated with studies of metacognition. When a student is asked to self-report they may be given a hypothetical or real problem to discuss. They are asked to either concurrently, retrospectively or hypothetically explain the strategies they might or have applied to the problem. The stated strategies are used as evidence of metacognition. In this study students were asked to solve two problems in the questionnaire and asked to record what they did. The interviewed students were asked to solve another problem and to talk through their thinking strategies. Students were not asked to talk aloud (as in some studies, for example, Lesgold, Lajoie, Logan, and Eggan, (1990) as they solved the problems because it is believed that the verbalisation of the approach to problem solving could create the effect it sought to monitor (Clarke, 1992 and 1996).

Types of tasks in the questionnaire

Two mathematics problems were included as part of the questionnaire for students to reflect on their thinking processes. One further problem was given to the students who were interviewed. All problems came from a teacher reference on problem solving book (Milton, 1986). They all had one right answer and were able to be completed within approximately five minutes. The problems were non-routine and chosen to engage students. They were purposefully challenging because it is recognised that some students do not have to reflect to solve many classroom mathematics problems (Fortunato, Hecht, Kehr Tittle, and Alvarez, 1991) and therefore the tasks would not provide an effective basis for reflection in the inventory section of the questionnaire.

All of the problems had the potential to engage students in visualisation and/or diagrammatic representation of the problem. One questionnaire problem and the interview problem required students to use the operations of multiplication or addition. The problems enabled students to select from a variety of approaches to solve the problems such as: trial and error, process of elimination and working backwards. There are other ways which the tasks may have been categorised, for example, Williams and Clarke, (1997) but such fine distinctions are unlikely to contribute to the analysis in this paper.

Inventory

The questionnaire was based around an inventory of metacognitive behaviors. Students were asked to indicate whether they always, sometimes or never did these things when they solved problems. This technique (sometimes called Likert scales, rating scales or self-report questionnaire) for monitoring metacognition has been used in other studies such as those briefly reviewed below. In the search of education literature, no inventories were found for assessing the metacognition of children at the grade six level in mathematics. Most inventories have been completed with students at tertiary or secondary levels.

The mathematics questionnaires used by Fortunato et al (1991) and Stacey (1990) were influential in the design of the initial questionnaire in this paper. Both were conducted with secondary school students therefore they needed to be simplified and modified for primary school age children. Neither Stacey or Fortunato et al used open ended questions in their questionnaires (like those used in this study) but they both provided the stimulus for thinking about ways to effectively tap the thought of student thinking.

Fortunato, et al (1991) designed statements which focused on various stages of student thinking while problem solving in mathematics: planning, monitoring the process, evaluation and execution of the problem. They acknowledged the contributions of Corno and Mandinach (1983) and Schoenfeld (1985) in the creation of the questionnaire statements. Stacey (1990) relied on Likert scales developed by herself, by Bourke (1984) and the version of Fennema-Sherman scales as adapted by Rowe (1988).

Other researchers have used this technique which is fundamentally similar to the method used in my research. In a study of metacognition in mathematics conducted in secondary schools, Goos (1995) used both Likert scales (based on the work of Clarke, Waywood and Stephens (1993) Mc Donough and Clarke, (1994), and Schoenfeld (1989) and open ended problems. She acknowledged the work of Garofalo (1987) and Schoenfeld (1989). Grubaugh and Speaker, Jr. (1991-2) used rating scales with college students to discuss and self-assess their metacognitive abilities in reading/writing and study skills. Grubaugh and Speaker, Jr. (1991-2) used the same basic model of metacognition as used in this paper (ie awareness, monitoring and regulating of one's cognitive processes.' (1991-2 : 45) but the language employed in the scales is complex and specific to the English domain.

The final design and implementation of the initial questionnaire was determined by the needs and capabilities of the sample and the study parameters. A combination of question types were included: Likert scales and open ended questions. Likert scales were chosen to form a part of the questionnaire and interview process in this study. The items were based on the behaviors specified in the Metacognitive Behavior Table (see appendice 1) and an examination of the literature. Open ended questions were considered essential to allow for unexpected or unanticipated answers which may suggest unthought-of relationships or hypotheses.

Biggs (1993) cautions about the development and analysis of inventories, reminding readers that factors related to the student, teacher and context cannot be ignored. This has been acknowledged in this study. Checks on context dependence, such as the interviews have been included.

Pilot study purposes

Before commencing a larger study it was deemed useful to validate the potential of the instruments for collecting useful data. The major purposes of the pilot study were to check interpretations of the questionnaire items, remove ambiguities and test the adequacy of response categories. Because of the complexity of the issues involved in this study, student understanding of the language employed in the questionnaire had to be trialled.

Sample

Questionnaires and interviews were implemented with two groups of children. One group were from an outer suburban school (A, n=8) and further questionnaires were given to an inner suburban school (B, n=7) group of grade six children. A total of 15 grade six children from two schools were given questionnaires. At school A, 5 of the 8 were interviewed immediately after the questionnaire implementation. None of the students from school B were interviewed.

The teacher at school A was given a simple questionnaire. This required her to indicate which metacognitive behaviors from the student questionnaire list she had emphasised during mathematics lessons.

Results from the student questionnaires administered at both schools were compared to see if general trends were possible or if results were peculiar to each setting only. The distribution of responses from school A was similar to that of school B.

Copies of the student questionnaire and student interview schedules are not included in this paper. Many parts do not pertain to issues discussed in this paper. Relevant sections are reproduced in the next section.

Results

This paper focuses on the analysis and interpretation of the student questionnaire and student interview data. An analysis of the teacher questionnaire has been completed but is only briefly reviewed in this paper. A more detailed analysis is reported elsewhere (Wilson, 1997). The findings will report on: 1. Findings about student metacognitive behavior and 2. The need to refine aspects of the research design and methods. The latter considers how effective the instruments were for gathering data on metacognition and raises questions for the main study.

1. Results about metacognition

Subjects have been grouped according to the similarity of their responses to particular items. Results of the metacognitive behavior items section of the questionnaire were represented diagrammatically as shown below. Where the number of responses for any cell was below n= 3 (20%) the cell was considered empty. The shaded cells indicate how most or all students responded. The diagrams took the following forms:

A. Students who said they always do this

Never	Sometimes	Always

B. Students who said they never do this

Never	Sometimes	Always

C. Students who said they sometimes do this

Never	Sometimes	Always

D. A spread of results. Where some students said they did and some said they did not.

Never	Sometimes	Always

Items which fell within types A, B and C were not considered useful because they did not discriminate between students. Type D showed a division between responses and that was considered interesting. It raises the question: What do the people in each group have in common?

NB. The metacognitive behaviors have been coded. This appears in the brackets next to each item by function as defined in the metacognitive model (Figure 1). The items have been included here as they appeared in the questionnaire.

Category D: The items which show a **range** of responses and therefore differentiate between students include:
b. Ask yourself a question about the problem. (awareness, evaluation and/or regulation)*
g. Think about what you'll do next. (regulation)
h. Go back and check your work. (regulation)

*The type of question students may be asking themselves may be very significant and needed to be followed up in the interview. For example, Are students asking a question about the requirements, what they know, their own abilities, how they could change their strategies? etc.

Using this classification scheme students (Category A) students responded that they **always**:
a. Think about what you already know. (awareness)
c. Think about what the problem is asking you to do. (awareness)
d. Make a plan to work it out. (regulation)
e. Try to remember if you have ever done a problem like this before. (awareness)

There were no items which fell within type B.

Students said they **sometimes:**
f. Guess the answer because it like a problem you've done before. (regulation)
i. Think about a different way to solve the problem. (regulation)
j. Change the way you are working.** (regulation)

**It is recognised that the response to this item could be misleading because you may on most problems, only sometimes change the way you're working. If you were metacognitive you would only change the way you were working if you needed to. Indeed all behaviors listed on the questionnaire could be present during problem solving sometimes. It is noted that all items of Category C type were regulation functions.

People often suggest that student reports of their behaviors are merely a recital of teacher's communicated values. In this study there was little correspondence between what the teacher said she did (from the metacognitive items list given to students) when instructing the class and what the students reported they did in the questionnaire. In the questionnaire the teacher noted what she emphasised during mathematics lessons. This did not relate directly to student responses. Interestingly, on category A items (where students demonstrated a range of responses) the teacher said she never instructed her students to ask questions about the problem (item b), that she sometimes asked them to think about what they would do next (item g) and that she always asked students to go back and check their work (item h). All items and categories were analysed in a similar way to compare the student and teacher responses. No clear connection was made.

Metacognition: The connection between awareness, evaluation and regulation

The model of metacognition as defined in this paper has been checked for consistency with the results of this study. While the data analysis results are consistent with the hypothesised sequence suggested, evaluation of the data collection methods used concludes that the development of further instruments is required to confirm the link between the metacognitive functions of awareness, evaluation and regulation. For example, Do these functions need to always happen in this sequence? Does the data prove that students do not regulate unless they are aware of their thinking and evaluate their thinking?

2. Research design and methods

The pilot study revealed a need to change some aspects of the student questionnaire and interviews. Aspects of the design needing fine tuning and reconsideration are listed below.

a. Changes to the questionnaire

Language and Items: At a minor change level, results from the study demonstrated a need to simplify the language and reformulate some questions. It appeared that some questions also needed to be more specific. For example, Question (b) asked students if they 'Ask themselves a question about the problem.' Responses did not indicate which specific metacognitive function was in use. This question could include examples about what question students might be asking themselves, such as: about their thinking or about the way to solve the problem.

The questionnaire items should have asked students to reflect on the task they had just done (current metacognition) and what they usually do when they solve mathematics problems (retrospective reflection). Of more importance the analysis of the questionnaire data demonstrated a need to add more items to the questionnaire. An uneven number of items related to the different functions of metacognitive thinking behaviors was found. More evaluation items were needed.

Tasks: Pilot questions were trialled prior to the implementation of the pilot study. During trialling of the intended pilot questions, a problem was encountered when children were asked to recall decisions they made during mathematics problem solving. When routine mathematics equations were chosen by children to represent mathematics problem solving they did not reveal metacognitive thinking. To correct this problem, the final draft of the pilot questionnaire included non-routine problems for children to solve. This created other difficulties such as, the choice of appropriate problems, what number of problems should be included, the fact that the problem was out of context etc. In order to increase the chances of getting responses which would illuminate metacognitive thinking, the decision was made to include non-routine problems, creating a common reference point and context for research subjects.

Although the use of non-routine problems was more effective in stimulating and reporting metacognitive thinking than the use of the use of routine problems, three different types of problems will be used in the main study. These will include one spatial task, one task involving calculation and another task requiring students to use logic.

Other strategies cited by students

Some students responded to the last open ended question in the questionnaire which invited them to add anything else they do when they solve mathematics problems. This question was included to check that all possible responses were allowed for. Most of the strategies listed by the subjects were low level strategies, many were about how to get started or not specific enough to be illuminating. One student said "think logically and carefully." Unless specified the responses were stated between 2-3 times. The responses included:

- Read the question
- Write it down
- Use gimmicks
- Asks others (4 responses)
- Use visual aids/representation, for eg, diagram, fingers, pictures in the mind. (Most frequently stated, 6 responses)

Many of these strategies listed by students may have been consciously used as a result of their Awareness or Evaluation of their thinking or to change their way of working (Regulation). Students may have done these things as part of their 'usual ways of working' or as suggested by their teacher. This possible interpretation of the questionnaire data would be need to be verified through student interview. Further research would need to consider whether some items on the questionnaire need to include aspects of these student responses.

b. Student Interviews

The interviews provided the opportunity to follow up discrepancies between individual questionnaire responses on different tasks and for students to clarify questionnaire responses. The interviews also provided the opportunity for the researcher to observe students as they solved another problem and to record student comments about the strategies they used.

The interviews were disappointing as they were not very revealing in terms of additional data about metacognitive thinking, beyond that already provided by the questionnaire. Many student responses highlighted the difficulty students had reporting on their own thinking. For example, when asked about the strategies they used when solving mathematics problems many students responded as such: “Don’t know”, “It came automatic”, ‘It just hit me”, ‘Just known before’ and “Did it in my head”. Sometimes these response were followed by comments offering insight into student thinking. For example, the following two quotes suggest that regulation of thinking may be related to the perceived importance of the task. These responses followed a question about whether students assessed themselves in mathematics.

> “Yes, occasionally I think about how I could have done it better. ...When I understand it's easy. I think about my answers and if it's good and correct. If I could do it a better way. Try different ways. Even try them, sometimes. If I think it's a better way to do maths questions and you get better marks I'd probably write it out better-if it's like a test. If it's like normal classroom maths, I always try hard but I put more effort into a test." Student A

> "Don't know. When I do maths I just think about the question- only if it's a test because that's really important. I think I'm getting it wrong and then I surprise myself. How could I improve? I don't like practising." Student B

Tests seemed to provide the motivation for encouraging action. Harris and Bell (1986) and Tang (1994) support this notion. They argue that students’ awareness of assessment and perceptions of the assessment demands can effect their attitude and learning approaches.

Discussion

The findings of the pilot study raise many questions about the assessment of metacognition. They have acted as a vehicle to draw conclusions about research design and have implications for the main study. In this study (and others) defining metacognition and relating this definition to methods for reliable data collection for detecting metacognition has presented a methodological challenge. These difficulties and limitations have been discussed within this paper.

Analysis of the pilot study supplemented by additional readings of the research literature suggest particular key findings and associated action which are required for the design a reliable and valid study to assess metacognition. The proposed actions respond to the objections and findings, and provide direction for further research.

Key Findings and Action

Key Finding One

Existing definitions of metacognition are insufficiently precise and difficult to interpret in operational terms.

Action One

Refine the Metacognitive Behavior Table and inventory items to use to assess student metacognitive behavior.

Key Finding Two

Self-reporting appears to be a valid method for researching metacognition when used in conjunction with other reliable methods and checking procedures.

Action Two

Design the data collection to minimise minimum time between the questionnaire and interviews. Corroborating evidence should be provided to substantiate and elaborate questionnaire responses. For example, through an interview and/or others' observations by the teacher and/or a researcher. To realise this goal, the teachers would need to be provided with a definition of metacognition and asked to rate their students' metacognitive and mathematics abilities.

Conclusion

The model of metacognition and inventory as reported in this paper appear to be viable and effective in guiding both data collection and analysis but new data collection instruments need to be considered. An assessment strategy for metacognition would be more attractive to teachers if it could be used as an integral part of instruction. The design of such a useful instrument is a central goal of the research project of which this study was the first stage. Further work is currently being undertaken to this end.

In this paper it has been argued that assessment practices must move beyond the basics. If assessment of students' metacognitive thinking is not integral to teaching and learning, the improvement of student metacognition cannot be assumed. Only a basic curriculum and education for our students can be expected.

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Appendice 1. Metacognitive Behavior

This table shows what students may be thinking about when they are reflecting on their thinking as well as indicators of metacognitive behavior.

1. Monitors
When children monitor their thinking (awareness and/or evaluation) they ask questions, self-assess and make links between ideas.

Metacognitive Thinking **a. Monitoring Self**	**Metacognitive Behavior**
• own thinking about: learning	Self-assesses learning Questions learning,
own abilities	Self-assesses own abilities Questions own abilities
own progress	Self-assesses own progress, Questions own progress
own thinking	Self-assesses own thinking Questions own thinking Links current and previous ideas
own behavior	Self-assesses own behavior, Questions own behavior

b. Monitoring Practice	
•tool use	Asks a question about requirements Relates to another idea/task Makes prediction based on another idea/task Lists other ways to approach task
•choice of strategy	Self-assesses choice of strategy Asks a question about the choice of strategy
•own use of strategy	Self-assesses their own use of strategy Asks a question about their own use of strategy

2. Regulates
When children regulate their thinking they make lists, decisions, self-correct, select and change their ways of working, set goals and plan action.

Metacognitive thinking **a. Regulating Self**	**Observable Behavior**
•learning •thinking •behavior	Self corrects own learning Self corrects own thinking Self corrects own behavior
	Makes a plan Sets goals

b. Regulating practice	
•strategy use	Selects a new strategy

24

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