

# Evaluating and improving the mathematics teaching-learning process through metacognition

**Annemie Desoete**

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Department of Experimental Clinical and Health Psychology,  
Ghent University & Arteveldehogeschool

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**Belgium**

*Annemie Desoete*. Ghent University and Arteveldehogeschool, Department of Experimental Clinical and Health Psychology. Ghent University/Artevelde/SIG. B-9000 Ghent. Bélgica. E-mail: Anne.Desoete@UGent.be

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## Abstract

**Introduction.** Despite all the emphasis on metacognition, researchers currently use different techniques to assess metacognition. The purpose of this contribution is to help to clarify some of the paradigms on the evaluation of metacognition. In addition the paper reviews studies aiming to improve the learning process through metacognition.

**Method.** A longitudinal study was conducted on 32 children to investigate the mathematical learning and metacognitive skills in grade 3 and 4. Metacognitive skills were evaluated through teacher ratings, think aloud protocols, prospective and retrospective child ratings and EPA2000. In addition we described ways to enhance mathematics learning through metacognition.

**Results.** Reflecting on the results of the present study there is evidence that how you evaluate is what you get. Child questionnaires do not seem to reflect actual skills, but they are useful to evaluate the metacognitive 'knowledge' and 'beliefs' of young children. Think aloud protocol analyses were found to be accurate, but time-consuming techniques to assess metacognitive 'skills' of children with an adequate level of verbally fluency. Teacher questionnaires were found to have some value added in the evaluation of metacognitive skills. The data showed that metacognitive skillfulness assessed by teacher ratings accounted for 22.2% of the mathematics performances. In addition, a literature review shows that metacognition can be trained and has some value added in the intervention of young children solving mathematical problems.

**Conclusion.** We suggest that teachers who are interested in metacognition in young children use multiple-method designs, including teacher questionnaires to get a complete picture of metacognitive skills. Taking into account the complex nature of mathematical learning, it may be useful to evaluate metacognitive skills in young children in order to focus on these factors and their role in mathematics learning and development. Studies also reveal that metacognition can be trained and has some value added in the intervention of young children solving mathematical problems. Our data seem to suggest that metacognitive skills need to be taught explicitly in order to improve and cannot be assumed to develop from freely experiencing

mathematics. It might be possible that with more time allocated to metacognitive instruction, the mathematics teaching-learning process may improve.

**Keywords:** Metacognition, Evaluation, Improvement, Teacher ratings, Think aloud protocols, Questionnaires.

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## Introduction

Despite the emphasis on metacognition, concepts mean different things to different people (Wong, 1996) and different methods to evaluate and improve metacognition are used (Tobias & Everson, 1996; Schraw, 2000). The purpose of this study is to help to clarify some of the metacognitive paradigms, to investigate the value of teacher ratings and to evaluate if metacognitive instruction might improve the mathematics teaching-learning process.

Nowadays, metacognition is recognized as an important mediating variable for learning. However, since Flavell introduced the term in the seventies of the last century, metacognition seems to have multiple and almost disjointed meanings and is often used in an overinclusive way. *Metacognitive knowledge* was defined as the knowledge one has about the interplay between personal characteristics, task characteristics and the available strategies in a learning situation (Brown, 1978, 1987; Flavel, 1987). At this knowledge-level at least, two components can be differentiated from one another (e.g., Cross & Paris, 1988; Veenman, 2005). *Declarative metacognitive knowledge* was found to be ‘what’ is known about the world and the influencing factors (memory, attention and so on) of human thinking (Jacobs & Paris, 1987). *Procedural metacognitive knowledge* can be described as the knowledge of ‘how’ skills work and how they are to be applied (Jacobs & Paris, 1987). Procedural knowledge is necessary, according to Montague (1992), to apply declarative knowledge efficaciously and to co-ordinate multiple cognitive and metacognitive problem solving. The metacognitive knowledge component helps children to know how to study a new timetable (procedural knowledge) making use of the awareness of previously studied number facts (declarative knowledge) and selecting appropriate study behavior (Desoete & Roeyers, 2006). *Metacognitive skills* can be seen as the voluntary control people have over their own cognitive processes (Brown, 1980). Brown (1978, 1987) distinguished between four types of skills: prediction (e.g., How difficult is this task?), planning (e.g., What shall I do to execute this task?), monitoring (e.g., What do I yet not know in order to attain my objectives?) and evaluation (e.g., Is my table complete to grasp the full meaning of this problem?).

Metacognitive evaluation techniques can be classified according to whether they are administered either prospectively, concurrently, or retrospectively to performance on a learning or problem solving task (Veenman, 2005). Examples of *prospective methods* are self-

report questionnaires and hypothetical interviews. Also *retrospective techniques*, both *questionnaires and interviews* have been applied to assess metacognition. In addition to prospective and retrospective techniques, *concurrent assessment*, such as think-aloud protocols, systematic observation of metacognitive skills and on-line registration of metacognitive activities can take place. Recently, more *indirect* and *multi-method designs* are being used (Veenman, Van Hout-Wolters & Afflerbach, 2006). In a *within-method design*, similar methods are applied either prospectively, or concurrently, or retrospectively. A combination of think-aloud protocols with systematic observations (within the concurrent measures) is an example of such a within-method approach. In a *within-time design*, different methods are applied together. Often these techniques combine prospective and concurrent or concurrent and retrospective measures of metacognition. In an *across-method-and-time design* different methods are applied at different times.

Despite the different evaluation techniques, a common conceptualization of metacognition has been well implemented in educational circles. Teachers, educators and therapists came to believe that it is worthwhile to promote metacognitive skills of students. Hartman and Sternberg (1993) have summarized the research literature in the field of improvement of metacognition. They presented four main approaches: promoting general awareness by modeling by teachers, improving metacognitive knowledge (knowledge of cognition), improving metacognitive skills (regulation of cognition) and fostering on learning environments. Although teachers still pay too little attention to the explicit teaching of metacognitive skills several studies point to the fact that metacognition needs to be taught explicitly in order to develop and to enhance mathematical problem solving skills.

The short overview clearly shows that metacognition can be improved but additional research is needed concerning the evaluation of metacognition. The present study aims to add some data on the value of teacher ratings.

## **Method**

### *Participants*

Subjects were elementary school children attending two schools in the Dutch-speaking part of Belgium. All 33 children were assessed at the middle of grade 3 and 4. All participants were fluent Dutch-speakers without histories of extreme hyperactivity, sensory impairment,

brain damage, a chronic medical condition, insufficient instruction or serious emotional or behavioural disturbance, following regular elementary education in Flanders for more than two years. The mean full-scale IQ of these children was 101.03 ( $SD=7.90$ ). Informed consent from a parent of each participant was obtained before starting this study. A teacher rating and different mathematics and metacognitive tests were used in this study

### *Measures*

#### Mathematics measures

The Kortrijk Arithmetic Test Revision (Kortrijkse Rekenest Revision, KRT-R; Baudonck et al., 2006) is a Belgian test on *arithmetic reasoning* which requires that children solve mental arithmetic (e.g.,  $129+878=_$ ) and number knowledge tasks (e.g., add three tens to 61 and you get  $_$ ). The psychometric value of the KRT-R has been demonstrated on a sample of 3,246 Dutch-speaking children from grade 1 till 6.

The Arithmetic Number Facts test (Tempo Test Rekenen, TTR; de Vos, 1992) is a numerical facility test which requires that children in grade 1 solve as many number fact problems as possible within 5 minutes (e.g.,  $5 \times 9 = _$ ). The psychometric value has been demonstrated for Flanders on a sample of 10,059 children (Ghesquière & Ruijsenaars, 1994).

#### Metacognitive measures

Metacognition can be assessed with off-line (prospective and retrospective), on-line and combined techniques. In this study the Prospective Assessment of Children (PAC) and Retrospective Assessment of Children (RAC) were used as off-line ratings for children. Teacher Rating were used as off-line rating for teachers. Thinking-aloud protocol analysis (TAP) were used as on-line technique. The Evaluation and Prediction Assessment (EPA2000) was used as combined (prospective and retrospective) assessment. All metacognitive and mathematics instruments were tested in previous studies in order to determine the usefulness for this age group and for the sensitivity in measuring individual differences.

#### *Off-line techniques*

The Prospective Assessment of Children (PAC), a child-questionnaire adapted from the MSA (Desoete, Roeyers & Buysse, 2001) for this research line, is a 25 item rating scale

questionnaire for children on metacognitive prediction, planning, monitoring and evaluation skills. Children have to indicate before solving any mathematical problem on a 7 point Likert-type of scale to what extent a statement (e.g., 'I control exercises I make') is representative of their behaviour during mathematical problem solving (1= never, 7=always). Metacognition was prospectively assessed one day before the real experiment. Cronbach's alpha for the PAC scale was .81 (26 items). For the PAC subscales Cronbach's  $\alpha$  were .74 (10 items), .55 (4 items), .75 (9 items), .70 (2 items) for orientation, planning, monitoring and evaluation respectively.

The Retrospective Assessment of Children (RAC), is the same 25 item rating scale questionnaire for children on metacognitive prediction, planning, monitoring and evaluation skills. Children have to indicate on a 7 point Likert-type of scale to what extent a statement (e.g., 'I controlled exercises I made') was representative of their mathematical problem solving behaviour on the past task (1= never, 7=always). Cronbach's alpha for the total scale was .89 (25 items). For the RAC subscales Cronbach's  $\alpha$  were .77 (10 items), .52 (4 items), .81 (9 items), .64 (2 items) for orientation, planning, monitoring and evaluation respectively.

Teachers' judgments were used since, although some researchers question the trustworthiness of these data, reviews indicate that those judgments can serve as worthy assessments of students' achievement-related behaviors triangulated with data gathered by other protocols (Winne & Perry, 1996). The Teacher Rating, which was created for this research line, is a 20 item rating scale teacher-questionnaire on metacognitive prediction, planning, monitoring and evaluation skills (e.g., the child never (1) / always (7) knows in advance whether an exercise will be easy or difficult). Furthermore teachers scored the mathematical and reading performances as well as the intelligence of children (e.g., very low compared to peers (1)/ very good compared to peers (7)). Cronbach's  $\alpha$  of .98 was found for the test score (20 items). For the teacher rating subscores Cronbach's  $\alpha$  were .97, .89, .91 and .90 for prediction, planning, monitoring and evaluation respectively.

### *On-line technique*

Thinking-aloud protocol analysis (TAP) has also been applied during three word problem solving tasks. Children were instructed to merely verbalize their thoughts during word problem task performance. In the case children fall silent; the assessor urged them 'to keep on

thinking aloud'. This thinking-aloud prompts made children think aloud during the whole problem solving. The protocols were transcribed verbatim and analyzed according to a metacognitive coding scheme on the presence of 40 activities derived from grounded analysis in previous studies in this age-group. All scores were also independently coded and controlled by the author. Areas of non-agreement were discussed with reference to the definitions of the skills and were resolved through mutual consent. In line with Veenman and Spaans (2005) a zero was given if the activity was absent, whereas a score of 1 was given if the activity was present. It was also possible to give half a point if the activity was initiated but not completed. Cronbach's  $\alpha$  of .88 was found for the total protocol analyses. For the subscales Cronbach's  $\alpha$  were .79, .60, .82 and .75 for orientation, planning, monitoring and evaluation respectively.

### *Combined technique*

The Evaluation and Prediction Assessment (EPA2000) (De Clercq, Desoete, & Roeyers, 2000) is a computerized procedure for assessing mathematics, prediction and evaluation. In the measurement of prediction skillfulness, children were asked to look at exercises without solving them and to predict on a 4-point rating scale, whether they will be successful in this task. Children had to evaluate after solving the different mathematical problem-solving tasks on the same 4-point rating scale. Children could give four ratings (1 absolutely sure I am wrong, 2 sure I am wrong, 3 sure I am correct, 4 absolutely sure I am correct). Metacognitive predictions or evaluations were awarded two points whenever they corresponded to the child's actual performance on the task (predicting or evaluating 1 and doing the exercise wrong and rating 4 and doing the exercise correctly). Predicting and evaluating, rating 1 or 3 received 1 point whenever they correspond. Other answers did not gain any points, as they are considered to represent a lack of off-line metacognitive skillfulness. The three scores (prediction, mathematics and evaluation) were unrelated. For instance, in theory a child could obtain maximum scores for prediction, a zero score for mathematics and a medium score for evaluation. The psychometric value has been demonstrated on a sample of 550 Dutch-speaking third-graders (Desoete, Roeyers, & De Clercq, 2002).

### *Procedure*

All subjects were assessed in grade 3 and one year later in grade 4 individually, in a quiet room outside the classroom setting, where they completed the KRT-R (Baudonck et al., 2006) and TTR (de Vos, 1992). The regular teacher completed a teacher survey in the same period. A counterbalanced design was used. The prospective and retrospective task was per-



formed at the beginning and at the end of a mathematics test (KRT-R or TTR). All participants were instructed to think aloud while solving the three math problems. The psychologist only urged them to continue thinking aloud whenever they fell silent with a standard prompt 'Please keep on thinking aloud'. No help or feedback, whatsoever, was given by the psychologist. During the mathematics task, participants were provided no calculator but some blank sheets of paper for making notes. Sheets for note taking were removed during the KRT-R and EPA2000. The examiner, a psychologist, received practical and theoretical training in the assessment and interpretation of mathematics, and metacognition. The training took place two weeks before the start of the assessment. In addition, systematic, ongoing supervision and training was provided during the assessment of the first 5 children. The training included a review and discussion of the metacognitive profiles and involved one meeting during the assessment period.

## Results

Significant correlations were shown between the teacher rating of mathematics performance and the KRT-R ( $r=.53$ ,  $p<.01$ ), the EPA 2000 mathematics score ( $r=.63$ ,  $p<.01$ ).

To investigate the relationship between the teacher ratings on prediction skills and the assessment of prediction evaluated by other instruments Pearson correlations were computed between the prediction (see Table 1) and evaluation (see Table 2) measures .

**Table 1. Correlations among the metacognitive prediction skills.**

	Teacher ratings	PAC	RAC	EPA2000
TAP	-.12	.06	.02	.24
Teacher ratings	-	-.32	-.11	.54 **
PAC	-	-	.68**	-.24
RAC	-	-	-	-.01
EPA2000	-	-	-	-

\*\* $p<.01$

Significant correlations were shown between the teacher rating and the EPA2000 prediction score in pupils.

In addition, for the prediction measures, significant positive correlations were demonstrated between prospective (PAC) and retrospective measures (RAC).

**Table 2. Correlations among the metacognitive evaluation skills.**

	Teacher ratings	PAC	RAC	EPA2000
TAP	.02	-.13	-.27	.04
Teacher ratings	-	.03	.07	.55**
PAC	-	-	.40*	.12
RAC	-	-	-	.14
EPA2000	-	-	-	-

\*\*p&lt;.01

\*p&lt;.05

For the evaluation measures, significant positive correlations were demonstrated between the teacher rating and EPA2000. Children with good prospective evaluation skills (PAC) rated themselves also as good evaluators retrospectively (RAC).

To investigate the relationship between the teacher ratings on planning skills and the assessment of monitoring evaluated by other instruments Pearson correlations were computed (see Table 3).

**Table 3. Correlations among the metacognitive planning skills.**

	Teacher ratings	PAC	RAC
TAP	-.05	-.23	-.25
Teacher ratings	-	-.19	-.25
PAC	-	-	.57**
RAC	-	-	-

\*\*p&lt;.01

For the planning measures, no significant positive correlations were demonstrated between teacher ratings and skills assessed by think aloud protocols or child questionnaires. Children with good prospective planning skills (PAC) rated themselves also as good planners retrospectively (RAC).

For the monitoring measures, no significant positive correlations were demonstrated between teacher ratings and skills measured by think aloud protocols or child questionnaires (see Table 4).

**Table 4 Correlations among the metacognitive monitoring skills.**

	teacher ratings	PAC	RAC
TAP	-.22	-.03	-.03
Teacher ratings	-	.06	.06
PAC	-	-	1**
RAC	-	-	-

\*\*p&lt;.01

Children with good prospective monitoring skills (PAC) rated themselves also as good performers retrospectively (RAC).

The correlation between the teacher rating in grade 3 and 4 was  $r=.63$  ( $p<.01$ ). The correlations between EPA2000 in grade 3 and grade 4 were for prediction and evaluation  $r=.40$  ( $p<.05$ ) and  $r=.39$  ( $p<.05$ ) respectively. The TAP, PAC and RAC did not correlate significantly from grade 3 to grade 4.

To establish to what extent the metacognitive skills were associated with mathematics performance in third grade, a principal components analysis and a regression analysis were conducted. Given the high intercorrelations between the mathematics subtest scores) the internal structure of the mathematical data was first analyzed with a Principal Components Analysis, to account for all the variance. One component accounted for 59.46 % of the common variance. Since all variables were normally distributed and did meet the assumptions for multiple regressions, a regression analysis was conducted in the sample to evaluate how well the metacognitive skills measured by teacher ratings predicted the mathematics component. The metacognitive skills were included simultaneously as predictor variables. The linear combination of prediction, planning, monitoring and evaluation off-line measured by teacher ratings was significantly related to mathematics component ( $R^2$  was .22).

## Discussion and Conclusions

Since Flavell introduced the concept twenty years ago, different methods to assess metacognition have been used (Tobias & Everson, 2002). This study is devoted to teacher ratings (TR) to investigate if such a questionnaire can have some value added in the assessment of metacognitive skills of young children.

Overall, the results confirm the value added of ratings of experienced teachers (TR) as actual measures of metacognitive skills in elementary school children. Teacher ratings on

prediction skills correlated positively with the combined assessment by EPA2000 but not with the child questionnaire. The teacher questionnaire on evaluations skills also correlated positively with the concurrent and combined assessment techniques. Furthermore the rating of teachers on metacognition predicted for 22.2% the mathematics performances of grade 3 and 4 children.

In our study there seemed to be a fairly consistent mindset that was not much influenced by student's actual performances, resulting in similarity of ratings before (PAC) and after (RAC) mathematical problem solving. This is in line with previous findings (Desoete, Roeyers, & De Clercq, 2003) that metacognitive skills need to be taught explicitly in order to develop. They cannot be assumed to develop from freely experiencing mathematics.

These results should be interpreted with care, since there are some limitations to the present study. First it should be acknowledged that sample size is a limitation of the present study. Additional research with larger groups of children see indicated. Such studies are recently being planned. Second, the results of this study should be interpreted with care since the analyses are based on a two teachers. It might be so that less experienced teacher or teachers teaching different grades might lead to other results. In addition metacognitive skills may be age-dependent and still maturing. Finally, the number of other possible causes of low mathematical functioning (language problems, hyperactivity, sensory impairment, brain damage, a chronic medical condition, insufficient instruction, serious emotional or behavioural disturbance) was restricted to a minimum in this study. These restrictions, causing a limitation in the random sampling, have to be noted as limitations of this research. Additional research should focus on these factors.

Reflecting on the results of the present study there is evidence that the paradigm you choose to evaluate is what you get. Child questionnaires do not seem to reflect actual skills, but they are useful to get a picture of metacognitive 'knowledge' and 'beliefs' of young children. In addition to prospective and retrospective techniques, concurrent assessment, such as think-aloud protocols or a systematical observation of metacognitive behavior should take place. Think aloud protocol analyses were found to be accurate, but time-consuming techniques to assess metacognitive 'skills' of children with an adequate level of verbally fluency. Teacher questionnaires were found to have some value added in the evaluation of metacogni-

tive skills. We suggest that teachers who are interested in metacognition in young children use multiple-method designs, including teacher questionnaires.

Taking into account the complex nature of mathematical problem solving, it may be useful to evaluate metacognitive skills in young children in order to focus on deficient skills and their role in mathematics learning and development. Our data seem to suggest that metacognitive skills need to be taught explicitly in order to improve and cannot be assumed to develop from freely experiencing mathematics. Instruction should focus on the (meta)cognitive weaknesses or deficits and strengths of poor mathematical problem solvers, in order to tailor a relevant instructional program.

The central question now is whether and in what ways we can enhance mathematical problem solving through metacognition. Hartman and Sternberg (1993) have summarized the research literature in this field and presented four main approaches: promoting general awareness by modeling by teachers, improving metacognitive knowledge (knowledge of cognition), improving metacognitive skills (regulation of cognition) and fostering on learning environments. In the first approach of promoting general awareness, teachers *modeled* metacognitive skills and stimulated through a kind of reflective discourse the self-reflection exercises of students. Within the *improving metacognitive knowledge*-approach, teachers handed out overviews of successful approaches/strategies that moreover clarified how when and why to use specific strategies (e.g., Desoete, Roeyers & De Clercq, 2003). Children for example learned to slow down on more difficult tasks. They learned to activate prior knowledge, make a mental integration and build up diagrams. The third approach aimed to *improve* pupil's performance in mathematics by developing their *metacognitive skills*. This approach included presenting a variety of heuristics that are intended to support reflective activities focusing on planning, monitoring and evaluation. Content-dependent skills or strategies focus explicitly on concepts that support the learning of a specific content. In contrast, content-independent strategies are content-free and considered as general strategies. In the fourth type of approach training researchers focused on a 'powerful' *teaching environment*. These teaching environments fostered self-reflection, improvement, and helped students to attribute their success to the use of adequate strategies and self-regulation. Mevarech and Kramarski's method, IMPROVE is an example of metacognitive instruction that emphasizes reflective discourse by providing each student with the opportunity to be involved in mathematical reasoning. Teachers are trained to use metacognitive questions about the nature of the problem, the use of

appropriate strategies for solving the problem and the relationships with previous knowledge (Kramarski, Mevarech & Lieberman, 2001). This approach is in line with what Hartman (2001) identified as teaching "with" and "for" metacognition. This fourth type of methods often combines informed strategy training (influencing metacognitive knowledge) and self control training (influencing the metacognitive skills).

To summarise, metacognitive skills were found to be trainable. Students could learn to adopt a more orienting and self-judging learning approach, even through a very short metacognitive training. This metacognitive training improved pupil performance in mathematical problem solving and was found to have a sustained effect on mathematical problem solving. However, the metacognitive skills had to be explicitly taught to enhance mathematics. Skills did not develop spontaneously from exposure to well elaborated exercises (Desoete, Roeyers & De Clercq, 2003). Summarizing, although teachers still pay too little attention to the explicit teaching of metacognitive skills several studies point to the fact that metacognition needs to be taught explicitly in order to develop and to enhance mathematical problem solving skills.

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## Appendix A

### Prospective/ Retrospective Metacognitive Questionnaire Child

What characterizes you

How often did you display the following behavior the last 6 months during mathematics.

1 = never

7 = always

- PR 1 Thinking in advance if the exercises will be difficult or not
- E1 Controlling for made mistakes after answering
- PL 1 Working according plan
- Mo 1 Working slowly and more precisely in difficult tasks
- PR 2 Knowing in advance if one will be successfully or not
- MO 2 Changing strategies whenever the task demands this
- PL 2 Being able to tell how one will be completing the task
- E2 Remarking and correcting made errors afterwards
- PR3 Entirely reading the problem statement
- PR4 Underlining relevant information needed to solve the problem
- PR5 Taking note of important and unimportant information
- PR6 Reading a problem statement again
- PR 7 Making a drawing (or representation) of the problem statement
- PR 8 Writing down what I know and what is asked for
- PR 9 Working slow on difficult tasks

- PL 3 Taking time to selecting the numbers needed to solve a problem
- PL 4 Taking time to select the calculations needed to solve a problem
- Mo 3 Calculation correctness
- Mo 4 Systematically working on the problem solving steps
- Mo 5 Orderly note-taking of problem solving steps
- Mo 6 Working precisely and correct
- Mo 7 Checking calculations (calculating again)
- Mo 8 Checking the answer with the estimated outcome
- Ev 3 Reflecting on how a task was solved
- Ev 4 Reflecting on what went well, relating to future problem solving

## Appendix B

### Teacher Questionnaire

What characterizes the behavior of the child during the last 6 months solving mathematics problems, compared with children of the age.

1 = never

7 = always

- PR1            The child asks questions, looks and listens attentively to instructions and does not start immediately to solve the problem without exploring the problem
- PR2    The child can repeat instructions correctly and completely, if asked to do so
- PR3    The child analyses the relevant information needed to solve problems
- PR4    The child never starts without a plan
- PR5    The child can differentiates relevant and irrelevant information in a task
- PR6    The child can answer the question on how she or he will be completing the ask and where he or she will be attentive for
- PR7    The child reflects on task-relevant previously acquired knowledge on how she/he has to work and on the points were he/she has to be attentive
- PL1    The child relates new and previous knowledge on tasks
- PL2    The child is not satisfied with the first solution he of she finds
- PL3    The verbal answer is well prepared, complete and clear to understand
- M 1    The child works precisely and systematically
- PL 4    The child works according to the plan
- M 2    The child changes strategies whenever the task demands this without the teacher having to tell this

- M 3 After an intervention of the teacher or an independent acquired insight the child does not start all over but only changes what has to be changed
- M 4 After finishing a task, the child checks the calculations
- M 5 After finishing a task, the child checks the answer
- E 1 The child attributes failure to the correct internal and external factors
- E 2 The child can tell what was important to solve the task and what strategy went well
- E 3 The child reflects on future problem solving. In similar problems previous knowledge is not forgotten.
- M 6 The child works slowly and more precisely in difficult tasks

## Appendix C

### Coding metacognitive behaviour in Think Aloud Protocols.

Coding 0= behaviour is not present - 1=behaviour is present

#### Prediction/ Orientation

- PR1 Entirely the problem oriented on comprehension
- PR2 Underlining important words in the word problem
- PR3 Selecting the relevant information needed to solve the problem
- PR4 Reading the task again to comprehend it better
- PR5 Making a drawing related to the problem
- PR6 Puts the information needed to solve the problem together
- PR7 Writing down with own words what was asked for
- PR8 Writing down with own words what is already know
- PR9x Reflects on works carefully and slowly on difficult exercises and fast on easy parts
- PR10 Has some idea or estimates the possible outcome
- PR11 Other behaviour that points in the direction of metacognitive orientation

#### Planning

- PL1 Selecting relevant numbers/data to solve the problem
- PL2 Selection the calculations that will be needed to solve the problem and estimating a possible outcome
- PL3 Selecting relevant steps to solve the problem;
- PL4 Selecting relevant materials to solve the problem

- PL5 Taking time designing an action plan before actually calculating
- PL6 Other behaviour that points in the direction of planning

### Monitoring

- Mo 1 Adhering systematically to the plan
- Mo 2 Correct in calculation
- Mo 3 Makes correct use of unities and tens
- Mo 4 No unsystematic activities (varying two things the same moment)
- Mo 5 Makes notes related to the problem
- Mo 6 Orderly note-taking of problem solving steps
- Mo 7 Does not forget problem solving steps
- Mo 8 Orderly sequences of problem solving steps
- Mo 9 Acting according to the plan
- Mo 10 Monitoring the on-going problem-solving process, changing plan if
- Necessary
- Mo 11 Checking a calculation (calculating again)
- Mo 12 Checking the answer with the estimated outcome
- Mo 13 When answering, taking note of the precise answer
- Mo 14 Checking the results
- Mo 15 Referring tot the problem statement in the answer
- Mo 16 Reflecting on the answer and only if all is checked giving a clear, exact and precise answer
- Mo 17 Other behaviour that points in the direction of monitoring

Evaluation

- Ev 1      Summarizing the answer and reflecting on the answer
- Ev 2      Reflecting on what went well and how the tasks were solved
- Ev 3      Drawing a conclusion referring to the task
- Ev 4      Relating to future problems
- Ev 5      Relating to other problems

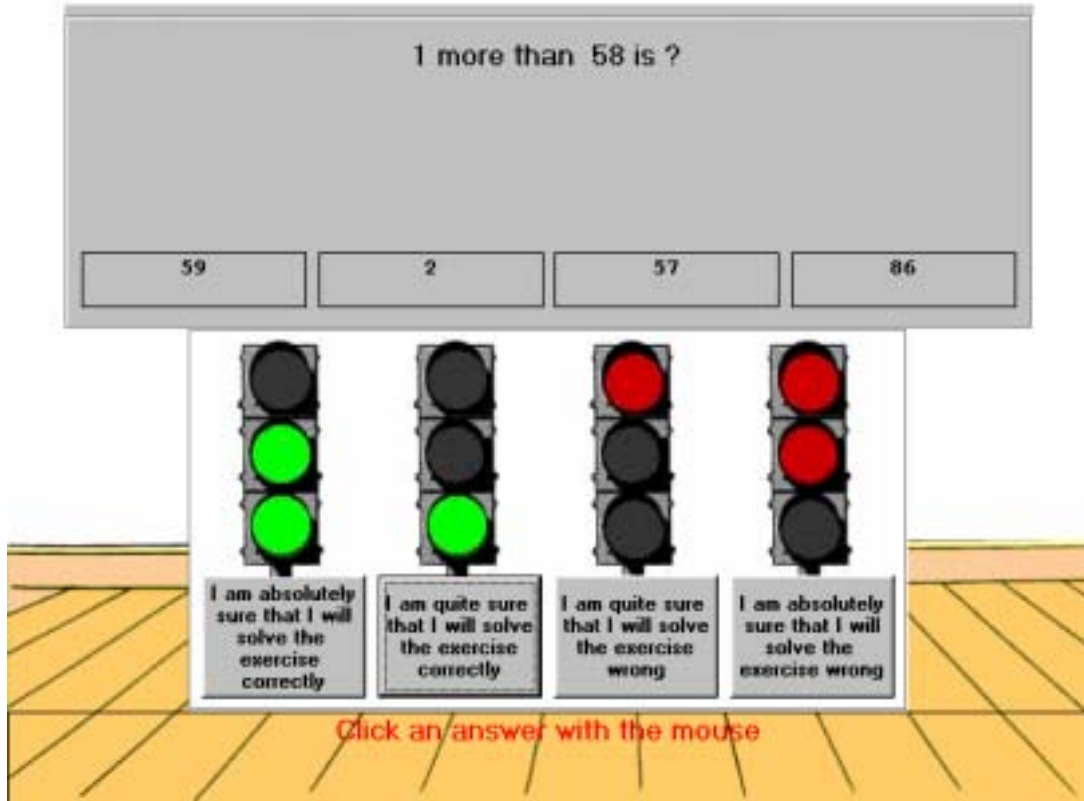
Note.

X=included in the analyses because there was enough variance in the scores of children on this parameter

## Appendix D

### EPA2000

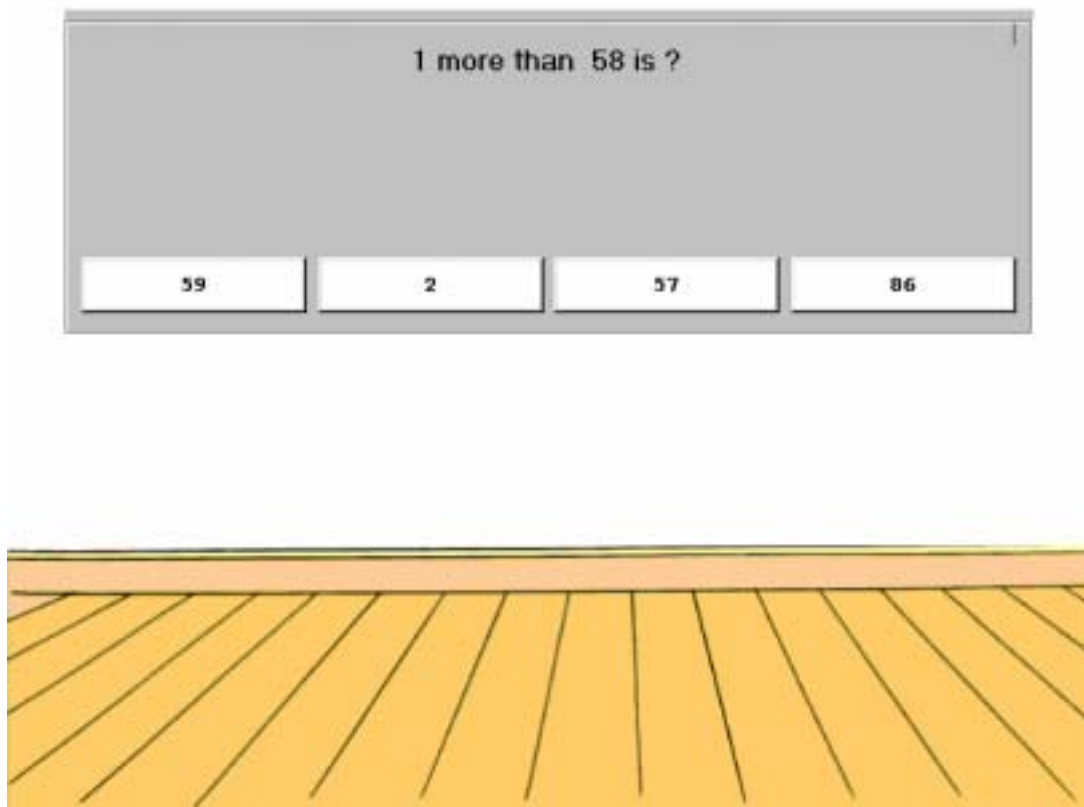
#### Prediction



EPA 2000 Prediction	80 items	Prediction skills (see baker- problem)	2 p = corresponding with the actual task 1 p = predicting rating 2 or 3 whenever they corresponded. 0 p = other answers
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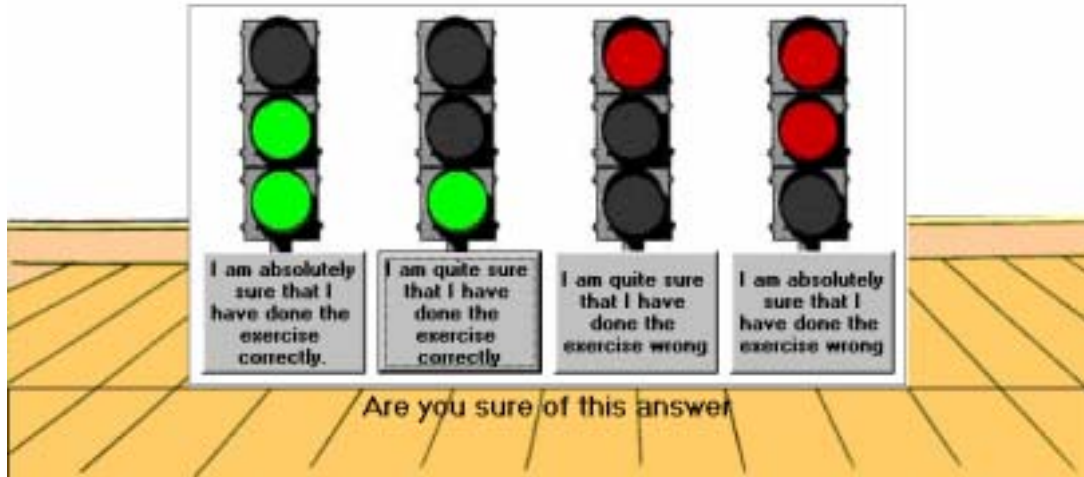


## Mathematics



EPA 2000 Cognition	80 items	Cognitive skills	1 p = correct answer 0 p = mistake
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Evaluation



EPA 2000 Evalua- tion	80 items	Evaluation skills	2 p = corresponding with the actual task 1 p = evaluating rating 2 or 3 whenever corresponding. 0 p = other answers
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