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# Metacognitive modelling competencies in small groups

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*Metacognitive modelling competencies are an essential part of modelling competence. When working on a modelling problem in small groups, the metacognitive modelling competencies of an individual may be less important, but in particular those shared in the group are of major importance. In this paper, results of a pilot study are presented which clearly indicate that measuring metacognitive group competencies is challenging. Furthermore, it is shown that the measurement of metacognitive competencies of individuals is not sufficient to get insight in the students' metacognitive behavior.*

*Keywords: Modelling competencies, metacognition, group work.*

## Introduction

Solving complex modelling tasks in mathematics education in school in Germany is usually done in small groups, at least in tandems. The reason for this is not the promotion of skills for cooperative collaboration - basic skills in this regard are taken for granted. Rather, there is the conviction that such complex problems can only be solved by students, if the ideas and skills of many are shared. This does not only refer to the so called sub-competencies of modelling competencies, which are necessary for getting from one phase of a modelling cycle to the next, but also concerning overarching skills such as metacognitive modelling competencies. However, in recent years, research on modelling competencies has merely focused on individual students. Thus, group dynamics were often neglected. This paper presents first results of a pilot study, in which students' perception and attitude towards metacognitive strategies used by themselves as well as by group members were measured by using different instruments for data collection.

## Theoretical background

### Modelling competence

Working on modelling problems successfully and goal-oriented requires modelling competence. Although there is no in general accepted concept about which competencies are comprised, the definition of Maaß (2006) is widely accepted. According to her definition, modelling competencies include “abilities and skills to conduct modelling processes adequately and in a goal-oriented way; as well as the willingness to put these abilities and skills into practice.” (Maaß, 2006) Here it becomes obvious that those competencies, necessary for getting from one step of a modelling cycle to another, are surely part of modelling competence (Kaiser, 2007). Furthermore, the definition given above, indicates that appropriate beliefs and insights as well as comprehensive competencies such as working cooperatively in groups, communicating with each other and metacognitive competencies are necessary as well.

### Metacognitive competencies

The concept of ‘metacognition’ is a fuzzy one. Schneider and Artelt (2010) define metacognition as “people’s knowledge of their own information-processing skills, as well as knowledge about the nature of cognitive tasks, and of strategies for coping with such tasks. Moreover, it also includes

executive skills related to monitoring and self-regulation of one's own cognitive activities." This definition provides the most common distinction of metacognition into metacognitive knowledge from metacognitive skills (often called metacognitive strategies). Thus, metacognition comprises metacognitive knowledge about the specifics of modelling tasks, the knowledge about appropriate strategies for working on modelling tasks successfully and knowledge about person's own skills and competencies and as well as those of other people involved the modelling activity. Furthermore, the procedural aspect of metacognition contains the use of strategies for planning, monitoring, regulating and evaluating the whole modelling process (see Vorhölter & Kaiser, 2016)

For solving a modelling problem successfully and goal-oriented, both aspects of metacognition mentioned above are necessary: A complete lack or only a very low level of meta-knowledge about modelling processes and problems can result in considerable problems when working on such tasks. For transitioning between the stages of a modelling process and for dissolving cognitive barriers while working on them, meta-knowledge as well as metacognitive strategies are needed (Maaß, 2006). Regarding problem solving processes, for example Schoenfeld (1992) points out the importance of planning the solution process. Furthermore, monitoring each other by reciprocal asking and answering metacognitive questions while working on a complex task can improve mathematical performance as well as metacognitive competencies at the same time (project IMPROVE, Mevarech & Kramarski, 1997). This finding is confirmed by the conclusion of Goos (1998): collaborative interactions deliver metacognitive benefits. However, not only metacognitive strategies referring to planning, monitoring and regulating the modelling process are of great importance for solving modelling problems: Blum (2015) points out that reflecting one's own activities is crucial for transferring knowledge and skills from one task to another.

### **Important metacognitive strategies for working on modelling problems in small groups**

The influence of metacognition on learning results was investigated in many studies, but the conclusions are ambiguous, as mentioned above. A reason for the ambiguity may be the fact, that metacognition is normally measured regarding a single person and correlates with her/his own mathematical performance. Solving modelling processes, however, is usually done in small groups. Therefore, one has to distinguish between the performance and metacognitive competencies of single team members and those of the group as a whole. But research on metacognition in the past has merely focused on individual processes. „By focusing on the individual student, researchers have failed to address the dynamics required for progressive knowledge building by collaborative learning groups“ (Chalmers, 2009). However, “team cognition emerges from the interplay of the individual cognition of each team member and team process behaviors.” (Cooke, 2004) So to solve a modelling problem successfully, not the individual, but the group competencies are crucial: Students have to share their knowledge and their competencies (Artzt & Armour-Thomas, 1992).

Thus, for working on modelling problems successfully in small groups, metacognitive strategies are of great importance. In previous studies at the University of Hamburg the following strategies were identified as those, that were used by students as well as classified as useful or even necessary:

- Strategies for planning:
  - P1: Subdivide the solution process in several steps,
  - P2: Allocate parts of work to different team members,

- P3: Structure the solution process according to the time available,
- P4: Choose useful solution strategies
- Strategies for monitoring and, if necessary, for regulating the working process
  - M1: Identify different kinds of red-flag-situations
  - M2: Notice incomprehension
  - M3: Keep track of the time available
  - M4: Check the work habits
  - M5: Reconsider solution strategies
- Strategies for evaluating the modelling process to improve it
  - E1: Evaluate the strategies used
  - E2: Reflect on the working habit
  - E3: Validate on the solution (cf. Schroeder, 2013)

The identified strategies were used for developing instruments for measuring students' use of metacognitive strategies while modelling, as shown in the next paragraph.

### **Measuring metacognitive strategies**

In general, for measuring procedural metacognitive modelling competencies, two possibilities exist: Online-methods such as thinking aloud, observations, eye-movement or logfile registration enable process diagnostics concurrent to task performance. Thus, a deeper look into the metacognitive behaviour of students is possible without disturbing and influencing them too much. However, these methods cost a lot of time and money. Therefore, they can only be used for small samples. While using offline methods like (prospective or retrospective) interviews or questionnaires, the results rely on the students' self-reports. These methods bear the risk that strategies may be used unconsciously or their use may be forgotten by the students. Furthermore, the item formulation may remind the students on the usefulness of certain strategies. Consequently, they will answer according to their metacognitive knowledge and not on basis of their behaviour. However, in contrast to observations and thinking-aloud-protocols, processes which were not verbalized because of different reasons can be measured with the help of questionnaires or interviews. In addition, questionnaires can be used for bigger samples. (Veenman, 2011).

For obvious reasons, the development of a questionnaire is desirable. For doing so, the identified metacognitive strategies mentioned above were used as a basis. The questionnaire used in this study consists of 40 items divided into the sub-processes of planning, monitoring, regulating and evaluating, 27 of them concern individual metacognitive strategies, 13 items regard group strategies. Students are asked to judge their use on a five-point-scale. Furthermore, students are asked to judge their motivation to work on the task, the task difficulty and their satisfaction with their small group. To give an impression of the questionnaire, selected items and the relation to the coding guideline presented above are shown in Table 1.

Item	Relation to coding guideline
1.1 I have thought about how to solve the Problem best on my own.	P1
1.2 We tried to recognize possible steps together.	P1
2.1 I questioned my own ideas.	M5
2.2 I questioned the others' ideas.	M5
3.1 When we found a solution, I reconsidered the whole solving process.	E1
3.2 When we found a solution, we were wondering what we can do better next time.	E2

**Table 1: selected items of the questionnaire**

## Research questions

As presented above, metacognitive competencies seem to be necessary for working on modelling processes successfully. Therefore, teaching units for fostering these kinds of competencies are desirable. To evaluate these teaching units, instruments for measuring metacognitive competencies are needed. Thus, a questionnaire for measuring students' individual metacognitive modelling competencies as well as those of a small group was developed. In the study presented in this paper, the students' self-reports in the questionnaire were compared to experts' ratings on the students' use of metacognitive strategies while working on a modelling task and to students' self-reports in an interview afterwards. Hence, the research questions of this study are:

- *For which metacognitive strategies – at an individual as well as at group level - do the students' statements in the questionnaire correspond with experts' ratings as well as with students' statements in interviews?*
  - *Which metacognitive strategies can be measured more reliable by students' self-reports?*
  - *Is any further information required to interpret students' self-reports?*
  - *Which metacognitive strategies can be measured more reliable by experts' ratings?*

## Design and methods of the study

For answering these questions, students of grade nine of three different classes were introduced to a modelling cycle and then worked in groups of four on a modelling problem. The working process was videotaped. After working on the problem, the students were asked to fill in the questionnaire presented above. While doing so, they were not allowed to speak to each other and discuss the items. In the afternoon, students were interviewed using a stimulated recall-interview (Gass & Mackey, 2000). For this, selected scenes from the video were shown to them and they were asked to comment them. Afterwards, some questions about their attitude towards the importance of metacognitive strategies were posed.

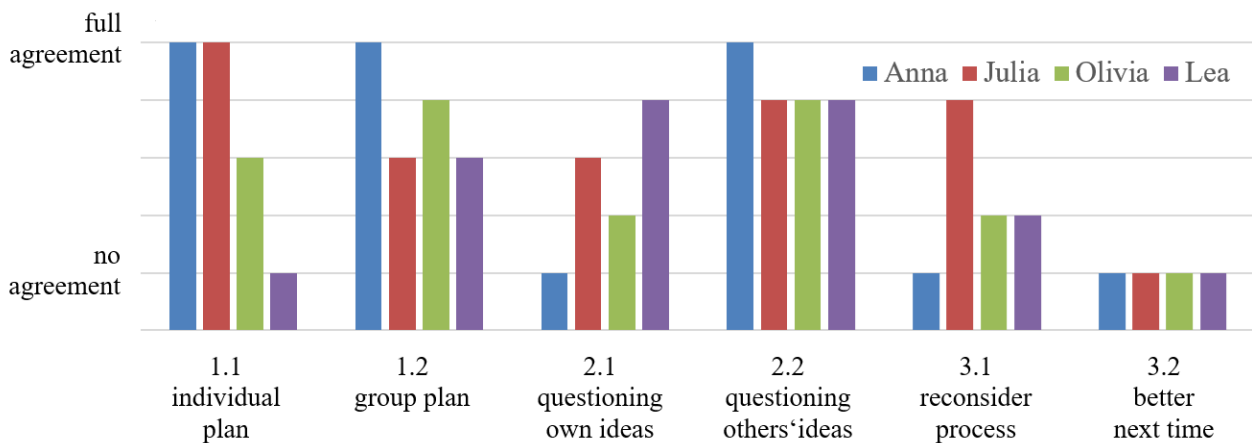
To answer the research questions, the videos as well as the interviews were analyzed using the items of the questionnaire as coding guideline, following qualitative content analysis (Mayring,

2010). Those codings were compared with the answers in the questionnaires. In the next section, first results from the study of one of the small groups are presented.

### First results of the study

The group consists of four girls, which are named Anna, Julia, Olivia and Lea in this paper; three of them were interviewed afterwards. Anna, Julia and Olivia all mentioned in their interviews that they were used to work together in this group; Julia indicates in the interview, that Lea is a new student and is not familiar with the other students. She assumes that this might be the reason for Lea not taking part during group work.

In the following, special attention is paid to items that were answered very differently by the students within the small group or items for which the different sets of data provide different information. Thus, students' statements in the questionnaire concerning selected items of the sub-processes of planning, monitoring and evaluation will be compared with the respective statements in the interviews as well as with outcomes of the analysis of the videos. An overview of the students' statements in the questionnaire is shown in Figure 1.



**Figure 1: selected students' judgements in the questionnaire**

In the questionnaire, Julia and Anna indicate that they worked out a plan on their own before planning the solving process together, whereas Olivia only did this partly and Lea did not plan on her own at all. Their perception of developing a plan in the whole group differs (see Figure 1). Thus, questions on the causes of these differences arise. When analyzing the video, one can clearly identify a scene in the beginning, in which the group is discussing how to proceed. You can see that Anna is the one, who develops a plan, whereas Julia and Olivia are not convinced and ask several questions. Before their questions are answered satisfactorily and before they are convinced, Anna starts to work. This scene was shown to the girls during the interview. When asked to comment on the scene, Olivia did not say much about the planning process:

Interviewer: How did you proceed in this situation?

Olivia: I don't really know. Actually, Anna said we should use a scale and then we knew what to do.

Only when asked about the necessity of having a plan, she talked about the importance of planning:

Olivia: Most times, planning is better, because you then know this is the next step, and then that step.

Anna on the other hand spontaneously commented her behavior:

Interviewer: In this scene, you have decided how to solve the problem. How did you decide?

Anna: I said how to, I don't know. We have. I had the idea of scale and then, Julia wanted to calculate the volume. But then we decided for the scale.

Summing up, the statements in the questionnaire express the level of conviction concerning Anna's plan. This suggests that the students' perspective on group planning was measured correctly, although the statements regarding group planning differ.

Regarding the sub-process of monitoring, both Anna and Olivia state in the questionnaire that they have not or only to a very small extent questioned their own ideas, but to a higher extend others' ideas (Table 1, 2.1 and 2.2). Comparing this data with those from expert ratings and from the girls' statements in the interview, different reasons for these statements are revealed. By analyzing the video of the girls' working process, Anna can be described as the one, who brought in the most ideas and managed the group in some ways. Although she wasn't aware of doing so during group work, she recognizes her behavior in the interview when asked to comment the scene:

Anna: I said that doesn't matter, I took over power and blocked other's suggestions and explanations. Seeing my behavior frightens me, I did not realize I was doing this.

Thus, her statement in the questionnaire indicates that she was a group leader that did not approve of others' ideas, because she was very convinced of her own. In contrast, Olivia did not participate with her own ideas or took over any other active responsibilities. However, it becomes clear from several statements that she was monitoring the whole process and questioned the process if necessary. But based on her statements in the interview, it becomes clear that she is not aware of doing so herself:

Interviewer: And what about looking about one's own shoulder? [...]

Olivia: I don't think so.

Interviewer: Why not?

Olivia: I don't know. We are a group that simply work. And then, ready.

Thus, Olivia uses metacognitive strategies of monitoring unconsciously. This makes clear that it is sometimes necessary to have further information about the group processes and the different roles of the students. One possibility are ratings by experts. However, those are not sufficient solely, as one can see in regards to Lea. She did not say a word while working on the problem, but states to have monitored the whole process. If her judgement is right, it cannot be proved. But as the answers from the questionnaire do not count regarding marks and it was clear to the students that their math teacher will not get their judgements, you can state that Leas statements are correspondent with her perception of her own behavior.

The students' statements about evaluating the whole modelling process correspond and match with the researchers' analysis completely: The group did not evaluate their working process significantly (except of Julia).

## Conclusion and outlook

The selected results of the pilot study presented above illustrate in a considerable way the importance of sharing metacognitive competencies in a group: Presumably, none of the girls would have solved the task on their own. Even Anna, the "group leader", needed Julia and Olivia for monitoring and validating the modelling process. However, it also becomes clear that measuring students' metacognitive competencies is challenging. Measuring metacognitive group competencies is even more challenging. In this study, different methods for measuring the use of metacognitive strategies while working on a modelling problem in small groups were used: students had to fill in a questionnaire and were interviewed. Furthermore, their behavior was judged by researchers.

The presented results clearly show that some answers in the questionnaire are not consistent with statements in the interviews or with the analysis of the students' working process. In addition, students' judgements about incidents during group work differ.

As presented above, almost all differences could be explained by consulting not only one, but different items or by using all three datasets. However, not all students, who take part in the main study (about 600), can be interviewed nor can their group work be analyzed. Therefore, it should be analyzed next, if there are any key or filter-items in the questionnaire that give information about how to judge other items. In accordance, the items have to be identified that can be rated by experts better than by students themselves and it has to be analyzed whether this is a question of special items in general or a question of students and the role of the students in small groups.

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