It's all about metacognitive activities: computerized scaffolding of self-regulated learning

Molenaar, I.

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7 Metacognitive Scaffolding during Collaborative Learning: A Promising Combination

Abstract This chapter explores the effect of computerized scaffolding with different scaffolds (structuring vs. problematizing) on the way metacognitive activities are embedded in the interaction among group members during collaborative learning. In this study, we investigate different types of interaction around metacognitive activities of 18 triads (6 control groups and 12 scaffolding groups (6 structuring and 6 problematizing)). We found that groups receiving scaffolding showed significantly more co-constructed metacognitive activities. Groups receiving problematizing scaffolds showed significantly less ignored and more co-constructed metacognitive activities compared to groups receiving structuring scaffolds. These findings indicate that scaffolding positively influenced the way metacognitive activities are embedded in the interaction among group members. Moreover, these findings seem to explain the differential learning effects of different forms of scaffolds. Therefore future research should consider how to design scaffolds that support metacognitive activities embedded in more transactive interaction.

Keywords ∙ Metacognition ∙ social systems ∙ Collaborative learning ∙ Elementary Education.

Chapter 7

Introduction

Cognitive and metacognitive activities are key to self-regulating one’s learning in Computer-Based Learning Environments (CBLE’s) (Azevedo, Moos, Johnson & Chauncey, 2010). Students who orientate, plan, monitor and evaluate learn more and show higher motivation than students who engage in less metacognitive activities (Azevedo, Moos, Greene, Winters, & Cromley, 2008; Land & Green, 2000; Veenman, Kok, & Blote, 2005). Additionally, metacognitive skills are an important predictor of students’ learning abilities, possibly even more important than intelligence (Van der Stel & Veenman, 2010). Even though the importance of metacognitive activities is recognized, students generally reframe from sufficiently regulating their learning in CBLE’s (Azevedo & Hadwin, 2005). Therefore, metacognitive scaffolding is used to foster student’s metacognitive activities (Veenman et al, 2005). In CBLE’s students often engage in collaborative learning in small groups (Stahl, Koschmann & Suthers, 2006). Metacognitive scaffolding has also been applied in small group settings showing similar results as in individual settings (Azevedo, & Cromely, 2004; Molenaar, van Boxtel, Sleegers, 2010).

In small groups, we speak of social regulation or social metacognitive activities that control and monitor the group’s cognitive activities (Iiskalla, Vauras, Lehtinen & Salonen, 2011Molenaar, van Boxtel & Sleegers, submitted). Social metacognitive activities are embedded in different types of interaction, which are associated with different amounts of transactivity (Molenaar et al., submitted). Transactivity refers to the extent to which group members relate to and engage in each other’s contributions in activities such as providing feedback, giving critical comments and engaging in arguments (Teasley, 1997; Weinberger & Fischer, 2006). Research indicates that the advantage of collaborative learning depends largely on the transactivity of the groups’ interaction (Webb, 2009). In line with these findings, we recently found that metacognitive activities embedded in more transactive interaction are more likely to facilitate the group process and that shared attention among the group members supports transactive interaction (Molenaar et al., submitted).

However up until now, we know little about the effect of scaffolding on the type of interaction metacognitive activities in small groups are embedded in. Interaction among students can be supported with different instructional designs, such as scripts, Jigsaw and role play (Dillenbourgh, 1999; Rummel & Spada, 2005). We do know that scaffolding stimulates the metacognitive activities of the group (Molenaar, van Boxtel & Sleegers, 2011) and consequently could influence the type of interaction these metacognitive activities are embedded in. Therefore, the question addressed in this chapter is: What is the effect of metacognitive scaffolding on the way metacognitive activities are embedded in interaction during collaborative learning in small groups? We will examine this question in an experimental study comparing students in a control group with students in an experimental group that received computerized scaffolding. Students in the experimental group are supported with two different forms of metacognitive scaffolds (problematizing vs. structuring scaffolds). Previously, we found that metacognitive scaffolding stimulates
metacognitive activities, which in turn enhances student’s metacognitive knowledge (Molenaar, Chiu, Sleegers & van Boxtel, in press). Different forms of scaffolds appeared to have a differentiating effect on student’s metacognitive knowledge, but not on the amount of metacognitive activities performed by the groups (Molenaar et al., in press). We proposed that the differences in student’s metacognitive knowledge could be explained by qualitative differences in the group’s metacognitive activities. In this study, we analyze this proposition examining the extent to which scaffolding influences the way metacognitive activities are embedded in the interaction between the group members. First, we elaborate on how metacognitive activities are embedded in interaction during collaborative learning. Second, we discuss how metacognitive scaffolding and different forms of scaffolds influence the group’s interaction.

**Metacognitive activities embedded in interaction**

Metacognition is defined as knowledge about and regulation of cognitive activities (Flavell, 1979). Different metacognitive activities such as orientation, planning, monitoring, evaluation and reflection regulate student’s learning (Veenman, Van Hout-Wolters, & Aflerbach, 2006; Zimmerman, 2002). In small groups metacognitive activities occur at various points along the social spectrum refered to as individual, other and social metacognitive activities (Iiskala, Vauras & Lehtinen, 2004, Iiskala et al., 2011; Hadwin & Oshige, 2011; Molenaar et al., submitted). Individual metacognitive activities regulate students’ individual cognition, whereas social metacognitive activities are directed at the group’s cognition. Other metacognitive activities are the regulation of individual cognition that is performed by another group member. The majority of metacognitive activities during collaborative learning are social metacognitive activities, but there also is a small proportion of individual and other metacognitive activities in the groups’ interaction (Molenaar et al., submitted). In this chapter, we focus on the social metacognitive activities that control and monitor the group’s cognitive activities. For example, group members orientate on their learning assignment, plan the group’s activities, monitor the group’s actions and evaluate the correctness of the group’s learning and finally reflect on the learning strategies followed by the group.

Social metacognitive activities are embedded in interaction between the group members (Iiskala et al, 2011; Molenaar et al. submitted). Collaborative learning research distinguishes different types of interaction among students associated with different degrees of transactivity (Wienberger & Fischer, 1996). We found that these different types of interaction also company social metacognitive activities. Social metacognitive activities in different types of interaction are called ignored, accepted, shared and co-constructed metacognitive activities (Molenaar et al., submitted). Most metacognitive activities are shared, as they are embedded in episodes in which the group members related to each other’s metacognitive contributions with new metacognitive remarks. There also was a substantial amount of accepted metacognitive activities that are immediately applied in the
group cognitive activities. Finally, there were quite some ignored metacognitive activities that are not take into consideration by the other group members and only a small number of co-constructed metacognitive activities, in which group members built on each other’s metacognitive contributions. The way metacognitive activities are embedded in interaction is important as metacognitive activities embedded in more transactive interaction are more likely to facilitate the group process (Molenaar et al., submitted).

Ignored metacognitive activities are not taken up by the other group members. Consequently, there is no transactivity in students’ interaction when students ignore each other’s contributions. Accepted metacognitive activities are applied in other group member’s cognitive activities and shared metacognitive activities are responded to with other group member’s metacognitive activities. When students accept or share each other’s metacognitive activities, they either relate to or engage in each other’s contributions. This indicates medium transactivity. Finally, in co-constructed metacognitive activities group members collaboratively built new metacognitive activities (Molenaar et al., submitted). When students relate to and engage in each other’s contributions, we speak of high transactivity. Thus, these four different types of interaction specify how metacognitive activities are embedded in the group’s interaction and indicate the level of transactivity (see figure 17 for an overview).

![Figure 17. Overview of different types of interaction in which metacognitive activities are embedded and their level of transactivity](image)

Different perspectives on collaborative learning all emphasize that students’ elaborations on each other’s contributions are essential for students to benefit from collaborative learning (Chi, 2009; Doise, 1990; Doise & Mugny, 1984; Hatano, 1993; Mercer, 1996; Piaget, 1932; van Boxtel, 2004; Webb, 2009). Transactive interaction supports group members to learn from each other through exchanging, sharing and co-constructing knowledge (Roschelle, 1996, Teasley, 1997; Weinberger, Stegemann & Fischer, 2007). Moreover, metacognitive activities embedded in more transactive interaction are more likely to facilitate the group’s process as they are developing,
activating or confirming cognitive activities that support the realization of the group’s learning goal (Molenaar et al., Submitted). Therefore, we expect that the way metacognitive activities are embedded in interaction is likely to influence the exchange of metacognitive knowledge among the group members. Ignored metacognitive activities do not support the exchanges of metacognitive knowledge among group members. Accepted metacognitive activities highlight successful metacognitive activities, which can add to metacognitive knowledge. Shared metacognitive activities support the exchange of existing metacognitive knowledge among the group members. Finally, co-constructed metacognitive activities support the collaborative creation of new metacognitive knowledge. Thus metacognitive activities embedded in more transactive interaction are likely to support the development and exchange of metacognitive knowledge among the group member, which consequently can be beneficial for individual group members. Yet, collaborating students in CBLE’s have difficulties to sufficiently regulate their learning. In the next section we discuss how scaffolding can support these small groups to perform metacognitive activities and how scaffolding is likely to also influence the way metacognitive activities are embedded in transactive interaction.

Effects of scaffolding on types of interaction among the group mates

Scaffolding is directed at stimulating students to perform activities they are unable to perform successfully by themselves (Wood, Bruner & Ross, 1976). Metacognitive scaffolds help students and small groups to perform the needed metacognitive activities to regulate their learning. We found that computerized metacognitive scaffolds provided by a 3D embodied agent stimulated small groups to engage in more metacognitive activities (Molenaar et al. 2010). Moreover, there are differential effects of different forms of scaffolds on students’ metacognitive knowledge which cannot be explained by quantitative differences in metacognitive activities (Molenaar, Ming, van Boxtel & Sleegers, in press). We therefore proposed that qualitative differences in metacognitive activities could explain these differences. These qualitative differences could be grounded in the way metacognitive activities are embedded in interaction. The question we raise in this study is to what extent can scaffolding and in particular different forms of scaffolds affect the way metacognitive activities are embedded in the interaction among students.

We know that different instructional designs support successful interaction among students (Dillenbrough, 1999; Rummel & Spada, 2005). Scripting, Jigsaw designs and role play all stimulate students to engage in more transactive interaction (Weinberger & Fischer, 2006, Dillenbrough, 1999, Strijbos & de Laat, 2010). For example, scripts provide procedural guidelines to support argumentation, which have been shown to increase the transactive interaction among the students (Weinberger & Fischer, 2006). Scaffolding can have a similar effect on student’s interaction as it also provides guidelines. Thus like scripting scaffolding provides interventions in the group process, which can influence the interaction among the group members. We can specify how scaffolding influences
interaction by looking at two mechanisms that explain how students learn from scaffolding (Reiser, 2004). Structuring simplifies the learning assignment by reducing its complexity, clarifying the underlying components and supporting performance (i.e. providing the students with an example of a plan for the assignment). Problematizing increases the complexity of the learning assignment by emphasizing certain aspects of the assignment and asking learners to clarify the underlying components and perform actions to construct their own strategies (i.e. asking students to make their own plan for the assignment). These different mechanisms support the formation of different forms of scaffolds that either structure or problematize aspects of the learning assignment.

We know that both of these forms of scaffolds stimulate more metacognitive activities in the group (Molenaar et al., 2011). It is likely that they also influence the type of metacognitive interaction the group. Structuring scaffolds give examples of metacognitive activities to the group as such performing part of the group’s regulation. An example of a structuring scaffold is to show students an exemplary plan for their mind mapping tasks: “What would you like to learn; let’s make a mind map with important topics to learn, for instance the climate”. These scaffolds support students to elaborate on this example adjusting and shaping the group’s plan for the mind map task (Molenaar et al., submitted). These types of scaffolds that provide explanations have been found to elicit students’ interaction (King, 1998; 2002). We expect that structuring scaffolds will mostly stimulate groups to engage in accepted and shared metacognitive cognitive activities, in which student either accept the proposed metacognitive activities or relate to each other’s comments about the example.

Problematizing scaffolds, on the other hand, pose questions that elicit students’ metacognitive activities. An example of a problematizing scaffold is asking students to plan their mind mapping task “How are you going to make the mind map?”. In response to the problematizing scaffolds students have discussions about (conflicting) views, exchange, share, or co-construct metacognitive activities together (Molenaar et al., submitted). Other research has also shown that question prompts elicit students’ explanations and support articulation of student’s thinking which initiates interaction (Chi, Siler, Jeong, Yamuachi, & Hausmann, 2001; Davis & Linn, 2000; King, 1998, 2002). Therefore, we expect that problematizing scaffolds will elicit more co-constructed metacognitive activities, in which students collaboratively construct new metacognitive activities.

Even though there are studies that show that scaffolds facilitate interaction, few studies systematically compared the effect of different forms of scaffolds on students’ interaction in small groups. Research does indicate that the interaction pattern between the group members tend to lock in early in their collaboration (Kapur, Voiklis & Kinzer, 2008). The group’s interaction generally remains quite stable throughout the learning assignment (Kapur & Kinzer, 2007). The advice is to support the group’s interaction early in the collaboration to increase transactive interaction (Kapur et al., 2008). This is
particularly important as our scaffolding system provides groups with scaffolds that are
dynamically integrated the group’s process during the first two lessons. Moreover
transactive interaction is also assisted by shared attention among the group members
(Barron, 2000, 2003; Molenaar et al, submitted). Group members are more likely to
develop transactive interaction, when they share a common focus of attention. Scaffolds
could focus the group’s attention on a common object. For example, the group receives a
scaffold indicating how to plan a particular task. All group members listen to the
scaffolding message, which focuses their attention on planning the task. Because the
planning of the learning task is now in the attention of all group members, they are more
likely to respond to each other’s comments and elaborate on planning their task.

To summarize the above, the main difference between scaffolding in an individual
and a group setting is the interaction among the group members. Transactive interaction
enhances the exchange, sharing and co-construction of knowledge among the group
members, which supports additional learning. We propose that metacognitive scaffolding
and different scaffolds can affect students’ interaction around metacognitive activities.
Once the interaction pattern is set, the group is likely to continue this throughout the
learning assignment. Moreover scaffolds could support transactive interaction between the
group members by focusing the group’s attention. In our study, students received scaffolds
to support their metacognitive activities. Until now we have established that metacognitive
scaffolding increases the number of metacognitive activities in small groups (Molenaar et
al, 2010) and that metacognitive activities embedded in more transactive interaction are
more likely to facilitate the group process (Molenaar et al., submitted). Thus if we can
establish that scaffolding and different forms of scaffolds affects the transactive interaction
in which metacognitive activities are embedded, this is likely to account for differential
learning effects of different forms of scaffolding.

This study

We report an experiment in which students in elementary school collaboratively worked on
a research task in a complex computer-based environment. There were three conditions,
two scaffolding conditions and a control group. Triads in the scaffolding conditions
received scaffolds to support their metacognitive activities; triads in the control condition
did not. Furthermore, the two scaffolding conditions received different forms of scaffolds;
namely problematizing scaffolds versus structuring scaffolds. We will analyze the effect of
scaffolding and different forms of scaffolds on the way metacognitive activities are embedded in the
groups’ interaction. This raises the following research questions:

1. What is the effect of metacognitive scaffolding and different scaffolds on the way
   metacognitive activities are embedded in interaction?
2. What is the influence of metacognitive scaffolding and different scaffolds on
   shared attention of the group?
We expect metacognitive scaffolding to elicit metacognitive activities embedded in transactive interaction among group members (transactivity hypothesis 1a.). This is based on the fact that scaffolds intervene in the group process and are thus likely to alter the interaction among group members. We expect problematizing scaffolds to elicit more co-constructed metacognitive activities compared to structuring scaffolds and structuring scaffolds to stimulate more accepted and shared metacognitive activities compared to problematizing scaffolds. This is based on the fact that problematizing scaffolds elicit group members’ constructive activities in interaction compared to a discussion of how to apply the example that are stimulated by structuring scaffolds (transactivity hypothesis 1b.).

Moreover, we also expect that scaffolding will elicit shared attention among the group members (shared attention hypothesis). This is based on the expectation that scaffolds focus the attention of different group members. We do not expect a differentiating effect of different forms of scaffolds on shared attention.

Finally, we want to establish if groups in the scaffolding conditions continue to show more transactive interaction throughout their collaboration. The transactivity in the interaction will be measured analyzing the triads’ metacognitive episodes. If the transactivity hypothesis holds, we expect triads who receive scaffolds to show more metacognitive activities embedded in transactive interaction. Additionally we expect triads in the problematizing condition to outperform triads in the structuring condition on co-constructed metacognitive activities. Whereas triads in the structuring conditions show more accepted and shared metacognitive activities. If the shared attention hypothesis holds, we expect scaffolds triads who receive scaffolds to elicit more shared attention at the beginning of metacognitive episodes than triads who did not receive scaffolds.

Participants

Due to the labor intensive nature of discourse analysis, we could not analyze all triads that participated in the full study (Molenaar et al, 2010). In the full study, 156 students from 6 classes in 3 schools participated. The teachers assigned students to heterogeneous triads (52) through the following procedure. First, we asked teachers to rate the students as low, middle or high achievers based on their reading, writing and computer achievement. Then, the teachers created triads containing one low, one middle and one high achiever. Every triad had students of both gender. Next, we randomly assigned the triads to the three experimental conditions, equally divided across the classes: 16 triads with no scaffolds (control group), 17 triads with structuring scaffolds, and 19 triads with problematizing scaffolds, see section below on scaffolding for details. For this study, we randomly drew a smaller sample of 18 triads (one in each scaffolding condition from every class) for the process measurements. This sub-sample consists of 54 students (23 boys and 31 girls) in 6 control triads, 6 structuring scaffold triads and 6 problematizing scaffold triads. These 54 students were in Grade 4 (9), Grade 5 (27) or Grade 6 (18) in 3 elementary schools.
Virtual learning environment and assignment

The e-learning environment used in this study is called Ontdeknet. It focuses on supporting students in their virtual collaboration with experts (Molenaar, 2003). The experts provide students with information about their expertise, namely knowledge about their country for this study. The experts’ contributions were edited by the editor of Ontdeknet. The teacher gives the assignment and monitors students’ progress. Collaborative learning is implemented at two levels: students collaborating with an expert in a virtual environment and with each other face-to-face in small groups with a computer. The study consisted of 8 lessons, each lasting 1 hour. In the first lesson, the students completed a pre-test, and then received instructions about the assignment and the virtual environment. In the last lesson, the students completed several post-tests. All students received the same instructions, and all triads spent the same time working on the assignment (6 hours). During these 6 lessons, the triads worked on an assignment called “Would you like to live abroad?” The goal of the assignment was to explore a country of choice (New Zealand or Iceland), write a paper on their findings and decide if they would like to live in this country. The triads worked on one computer and had access to an expert, namely an inhabitant of the country. They could consult the expert by asking questions and requesting information about different topics about the country. In a separate expert window in the computer environment, the expert provided the requested information, and questions were answered in a forum. Four sub-tasks preceded the task to write a paper about the country: (a) introducing the group to the expert, (b) writing a goal statement, (c) selecting a country and (d) specifying topics of interest on a mind map. All tasks were integrated into the working space of the triads, where they also wrote the paper. The performance of the triads was stored in the learning environment. All lessons were supervised by the same researcher.

The scaffolding system and the conditions

Both types of metacognitive scaffolds were dynamically integrated into the computer environment. The triads of students in both experimental scaffolding conditions received computerized scaffolds supporting their metacognitive activities during the first two lessons at the same instance in the learning process (Molenaar, van Boxtel, Sleegers & Roda, 2010). These scaffolds were given when metacognitive activities are typically executed in the learning process. The timing was based on Zimmerman’s model for self-regulated learning (Zimmerman, 2002). The computerized scaffolding system determined the appropriate instance to send a scaffold based on the students’ attention focus. Students in the scaffolding conditions received a minimum of 12 scaffolds in each condition. The triads in the structuring condition (experimental group 1) received direct support for their metacognitive activities; for example, the computer avatar David showed the students an exemplary plan of a task “The expert would like to know what you want to learn. Please write all the topics about New Zealand that you would like to learn more about in this mind map” (see figure 18). In response, students can elaborate and reformulate the
specifications to the planning activities of group, see 18. The triads in the problematizing condition (experimental group 2) received scaffolds designed to elicit individual students’ metacognitive activities and explanations; for example, the computer avatar David asks, “How are you going to make a mind map?” The triads in the problematizing condition were obliged to answer the avatar’s questions in an answer box on the screen, (see figure 18). In response, students can construct a plan of how to make a mind map. Lastly, the control group triads saw the avatar David, but did not receive any metacognitive scaffolds. The avatar was included in all groups to control for a Hawthorne effect, in which its sole presence could influence the student activities, even without the actual scaffolding (Franke & Kaul, 1978).

Figure 18. Example of structuring and problematizing scaffolds

Measurements

The discourse analysis

The discourse of 16 groups (108 hours) was audio-taped, transcribed (51,339 turns) and analyzed in five steps. The reliability reported for every step is based on the coding of two independent raters that analyzed the discourse of 2 randomly selected triads (2500 turns). First, we detected the metacognitive activities in the groups (Molenaar et al., 2010). All turns were coded with mutually exclusive and exhaustive categories. The categories were cognitive, metacognitive, relational, procedural, off task, not-codable activities and teacher activity (see table 16 for an overview). There was excellent (Fleiss, 1981) agreement for these categories: the kappa was K=0.92. Cohen’s kappa was highest for the category metacognitive activities K=0.94 and lowest for category non-codable activities K=0.82.

Second, we determined the metacognitive episodes. Metacognitive episodes are sequences of turns that discuss the same topic and of which at least one turn is a metacognitive activity. The episode starts with the first metacognitive activity and ends with the last turn dealing with the same topic. An example of a metacognitive episode: “We start with the first chapter of our paper; What are we going to discuss in the first chapter?; Lets read the information about animals in New Zealand”. Two researchers independently
determined the metacognitive episodes of the 6 groups; the intercoder-agreement was 71%. All inconsistencies between the two coders were re-coded in mutual agreement.

*Table 16. Main categories of our coding schema.*

<table>
<thead>
<tr>
<th>Main category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metacognitive activity</td>
<td>Turns about monitoring and controlling the cognitive activities during learning</td>
</tr>
<tr>
<td>Cognitive activity</td>
<td>Turns about the content of the task and the elaboration of this content</td>
</tr>
<tr>
<td>Relational activity</td>
<td>Turns regarding the social interaction between the students in the triad</td>
</tr>
<tr>
<td>Procedural activity</td>
<td>Turns regarding the procedures to use the learning environment</td>
</tr>
<tr>
<td>Teacher/researcher</td>
<td>Turns that are made by the teacher or the researcher.</td>
</tr>
<tr>
<td>Off task</td>
<td>Turns that are not relevant to the task.</td>
</tr>
<tr>
<td>Not codable</td>
<td>Turns that are too short or unclear to interpret</td>
</tr>
</tbody>
</table>

Third, we determined the form of metacognitive activities namely individual, other or social metacognitive activities in the episodes. Individual metacognitive activities occur when one student is regulating his or her own cognitive activities; for example “Stop I need to think about this”. Other-metacognitive activities occur when a group member regulates the individual cognitive activity of another group member, for example “What are you doing?; I am trying to understand this question”. Social metacognitive activities occurs when one or more group members regulate their collaborative cognitive activities, for example: “What are we writing?; The goal statement; What is the goal statement?; That is where you write what you want to learn”. Cohen’s kappa was 0.91 which indicates excellent agreement (1981).

Fourth, we established if there was shared attention among the group members at the start of the metacognitive activities. In case the topic discussed in the episode was talked about in the turns preceding the metacognitive episode, we coded it as in the group’s shared attention. An example of a metacognitive episode shared in attention is “In New Zealand there are much different animals; This is wrong we cannot write there are much different animals; Ok lets write many different animals”. In this example, the topic is “In New Zealand there are many different animals”. This sentence is in the group’s shared attention, as two group members are contributing to the construction of the same sentence, when one group member monitors that the sentence is wrong. An example of a metacognitive episode not shared in attention: “In New Zealand there are many different animals; We need to discuss the language too”. Here a group member introduces a new topic to discuss in the group’s paper, when the group’s attention is focused on constructing the sentence. Cohen’s kappa was 0.72 which indicates acceptable agreement (Fleiss, 1981).

Fifth, for the social metacognitive activities which are a proportion of all metacognitive episodes, we distinguished four types of interaction around metacognitive activities: ignored, accepted, shared or co-constructed metacognitive activities. Ignored
metacognitive activities occur when the group members do not relate to nor engage in another group member’s metacognitive activity, for example: “Let's read this chapter; I am so happy”. Accepted metacognitive activities occur when the group members engage in a metacognitive activity with a cognitive activity, for example: “Let's write down hobbies; My hobbies are Tennis and Ballet”. Shared metacognitive activities occur when a group member relates to a metacognitive activity with another metacognitive activity, for example: “We do not know what to do next; true, but I do not know what to do either; What do you think?” Finally, when group members not only relate to but also engage in each other’s metacognitive activities, we speak of co-constructed metacognitive activities, for example: “Let's start again with the first part of the chapter; Ok what are we describing in the first chapter; We discuss the language of the country, let's read the chapter about language”. Cohen’s kappa was 0.86 which indicates good agreement (Fleiss, 1981).

Analysis

As mentioned earlier, the purpose of our study is to determine the effect of scaffolding and different forms of scaffolds on the interaction in which metacognitive activities are embedded and on the group’s shared attention at the beginning of these metacognitive episodes. As a consequence the analyses were done at the triad level. To test the transactivity hypothesis, we assessed the interaction of the triads using discourse analysis. The total dataset entails 108 hours of lessons and 51,339 utterances with 3702 metacognitive episodes of which 3519 were social metacognitive episodes. The distributions of the variable co-constructed metacognitive activities was not normal, it had a skewness to the left. Therefore, we decided to use the Mann-Whitney test to evaluate the hypothesis. We first tested the effect of scaffolding comparing the scaffolding group to the control group; next we assessed the effect of different forms of scaffolds comparing the problematizing and structuring group. Before we started to answer our research questions, we analyzed if the triads receiving scaffolding perform more metacognitive episodes than triads in the control condition. Even though the experimental group (mdn =211) did not outperform the control group (mdn = 165) significantly (U=21, p, 0.09 (one sided), r=0.25), we decided to use relative frequencies due to the small to medium effect of scaffolding on the number of metacognitive episodes. There was no difference in the number of metacognitive episodes performed between the structuring (mdn=212.5) and the problematizing condition (mdn=209.5): U=18, p=0.53 r=0). The mean reported indicates the relative frequency, for example the mean for ignored metacognitive activities in the control group was 0.22 thus 22% of all social metacognitive episodes in the control group. We decided to report the mean, because is a more intuitive number compare to the median. The effect sizes are calculated using the effect size estimate r, following Rosenthal (1991) defining 0.1 as a small effect, 0.3 as a medium effect and 0.5 as a large effect.
**Results**

*Influence of scaffolding on the type of metacognitive interaction*

It appeared that triads in the experimental group (m=0.09) showed significantly more co-constructed metacognitive activities compared to the control group (m=0.05), (U=15.5, p=0.03 (one sided), r=0.45). The other comparisons were not significant. Triads in the experimental group (m=0.20) show somewhat less ignored metacognitive activities compared to triads in the control condition (m=0.22), (U=26, p=0.19 (one sided), r=0.23). The experimental group (m=0.29) showed less accepted metacognitive activities compared to the control group (m=0.32), (U=20.5, p=0.08 (one sided), r=0.34). Finally, the experimental groups showed somewhat more shared metacognitive episodes (m=0.42) compared to the control group (m=0.41) (U=26, p=0.19 (one sided), r=0.22). Figure 19 provides an overview of the mean percentages of metacognitive activities embedded in interaction in control and the scaffolding condition.

With respect to the effect of different forms of scaffolding on the metacognitive activities embedded in interaction, we found that triads in the problematizing condition (m=0.18) showed significantly less ignored metacognitive activities compared to the structuring condition (m=0.22) (U=6, p=0.03 (one sided), r=0.56) and significantly more co-constructed metacognitive activities (problematizing m= 0.13 and structuring m=0.05), (U=5, p=0.02 (one sided), r=0.60). The other comparisons were not significant: triads in the problematizing condition (m=0.29) show the same amount of accepted metacognitive activities as triads in the structuring condition (m=0.29), (U=18, p=0.53 (one sided), r=0) and the problematizing condition (m=0.40) showed less shared metacognitive activities compared to the structuring condition (m=0.44 ) (U=12, p=0.19 (one sided), r=0.28). Figure 20 provides an overview of the mean percentages of metacognitive activities embedded in interaction in the problematizing and structuring condition.
Influence of scaffolding on shared attention

We expected that scaffolding would focus the group’s attention. However, we found that shared attention at the beginning of metacognitive episodes is similar for all triads. The triads in the scaffolding condition (m=0.55) and triads in the control group (m=0.54) are comparable, (U=30, p=0.30 (one sided), r=0.13); and so are the triads in the problematizing condition (m=0.56) and the structuring condition (m=0.54), (U=13, p=0.24 (one sided), R=0.23). About half of all episodes is shared in attention and there is neither an effect of scaffolding nor of the form of the scaffolds.

Lasting effects of scaffolding on the groups’ interaction

The results reported include the whole time the students worked on the learning assignment, thus both during and after they received scaffolds. A close analysis of the time graphs of the groups receiving scaffolds shows that co-constructed metacognitive activities occur throughout the learning assignment. Also a close look at the time graphs of the groups receiving problematizing scaffolds confirmed that the co-constructed metacognitive activities were evenly distributed throughout the learning task.

Discussion and conclusion

This study aimed to investigate the effects of scaffolding on the way metacognitive activities are embedded in interaction. We proposed that scaffolding supports more transactive interaction and shared attention at the beginning of metacognitive episodes. Moreover we expect that different forms of scaffolding have a differential effect on transactive interaction; i.e. we expect problematizing scaffolds to lead to more co-constructive metacognitive activities compared to structuring scaffolds and structuring to lead to more accepted and shared metacognitive activities. We analyzed the discourse of 18 triads to answer our research questions.
We found evidence for the transactivity hypothesis. Triads in the scaffolding condition showed more co-constructed metacognitive activities than triads in the control condition. These results indicate that scaffolds can support groups to co-construct metacognitive activities. These findings concur with earlier findings of Barron (2000; 2003) regarding the difference between successful and unsuccessful groups. This distinction did not lie in the number of problem solving attempts of the group, but in the number of attempts that was taken up by the group in transactive interaction. Here we find the same: all groups show attempts to regulate their learning, but groups in the scaffolding conditions are more likely to get involved in co-constructive metacognitive activities, which in turn increase the likelihood that these attempts will facilitate the group process. Thus as proposed scaffolding indeed has an effect on the interaction in which metacognitive activities are embedded.

With respect to the differentiating effect of different forms of scaffolds, we found that problematizing scaffolds support more transactive interaction among the group members. Triads in the problematizing condition show more co-constructed metacognitive activities compared to triads in the structuring condition. Moreover problematizing scaffolds resulted in less ignored metacognitive activities than structuring scaffolds. We expected problematizing scaffolds to increase co-constructive metacognitive activities due to the fact that they ask students to construct their own metacognitive activities. However, we did not expect this would reduce ignored metacognitive activities. One possible explanation is that groups that co-construct more metacognitive activities increase the group’s shared metacognitive knowledge. Shared knowledge is more likely to be used among the group members (Engelmann & Hess, in press). Thus more shared metacognitive knowledge among the group members could be an explanation for the fact that less metacognitive activities are ignored by other group members. We did expect that group’s receiving structuring scaffolds would show more accepted and shared metacognitive activities. Neither was confirmed, both forms of scaffolds elicit equal amounts of accepted metacognitive activities. The effect on shared metacognitive activities was in the anticipated direction.

We raised the question if qualitative differences in the way metacognitive activities are embedded in interaction could explain the differential effects of problematizing scaffolds on metacognitive knowledge. The results of this study confirm our earlier proposed qualitative differences in metacognitive activities as a result of different forms of scaffolds (Molenaar et al., submitted). We proposed that problematizing scaffolds lead to more transactive interaction compared to structuring scaffolds. The findings suggest that the qualitative difference in metacognitive activities could explain the differential effects of problematizing scaffolds on students’ metacognitive knowledge.

Contrary to our expectations, we did not find that scaffolds increase students’ shared attention at the beginning of metacognitive episodes. It is important to remember that
students only received a small number of scaffolds during the first two lessons, after which scaffolding was ceased. Analyzing the shared attention after scaffolds were provided indicated that they did elicit shared attention, however this effect was not sustained beyond receiving the scaffolds. However, we did find previously that shared attention does support more transactive interaction (Molenaar et al. submitted). To check this for this sample, we calculated the ratio of shared attention prior to different types of interaction. The ratio of shared attention before ignored metacognitive activities was 40%, which indicates that 40% of the ignored metacognitive actives were preceded by shared attention among the group members. The ratio for accepted metacognitive activities was 56% and for shared metacognitive activities it was 58%. Finally, co-constructed metacognitive activities were started in shared attention 74% of the time. These findings indicate that more transactive interaction is indeed more likely to be proceeded by shared attention among the group members. Yet scaffolding does not stimulate more shared attention, which is probably due to the low number of scaffolds.

Moreover, we suggested that scaffolding could initiate lasting changes to the group’s interaction. Taking into account that scaffolds were only given in the first 2 lessons, it is important to know that the increase of co-constructed metacognitive activities in the scaffolding conditions was throughout the learning assignment and not just during the lessons that the groups received scaffolds. This is in line with earlier findings (Kapur et al., 2008) that indicated that the interaction pattern initiated in the beginning of the collaboration remains rather stable over time.

These results initiate a practical implication. We showed that metacognitive scaffolding positively influenced transactive interaction around metacognitive activities. Thus scaffolds could function as a instructional design supporting students’ to engage in metacognitive interaction during collaborative learning. Moreover, it seems that the effects of metacognitive scaffolding and different forms of scaffolds on learning are enhanced by the interaction between the group members. We therefore encourage further research into the design of scaffolds that optimize interaction. This opens up the line of thought about metacognitive scaffolding as an instructional design to support successful collaboration among students and to develop metacognitive knowledge and skills. The relation between scaffolding metacognitive activities and collaboration needs future research. It could be a promising combination to enhance student’s metacognitive knowledge and skills for future learning in complex computer-based environments.

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