It's all about metacognitive activities: computerized scaffolding of self-regulated learning
Molenaar, I.

Citation for published version (APA):
4 The Effects Scaffolding Metacognitive Activities in Small Groups

Abstract This study examined the effects of scaffolds on groups’ metacognitive activities in complex computer-based learning environment. In an experimental design, two experimental groups receiving scaffolds were compared with a control group (n=18). The experimental groups differed in the form of scaffolds used: structuring scaffolds (n = 18) vs. problematizing scaffolds (n=18). We analyzed the effects of scaffolding and the different forms of scaffolds on the amount of metacognitive activities of triads on the interpersonal plane. The results show that scaffolding has a significant effect on metacognitive activities; triads receiving scaffolds performed significantly more metacognitive activities on the interpersonal plane. Additionally, scaffolding also has a significant development effect; triads continue to show more metacognitive activities after the scaffolding is ceased. Finally, no significant differences between the two forms of scaffolding were found: triads receiving problematizing scaffolds did not show more metacognitive activities during or after the scaffolding compared to triads receiving structuring scaffolds.

Keywords Metacognitive activities · Scaffolding · Complex open learning environments · Virtual Agents · Elementary Education.

---

Chapter 4

Introduction

Students collaborating in small groups often have problems controlling and monitoring their learning in complex open learning environments such as electronic learning environments (Jacobson & Azevedo, 2008). Students find it difficult to set clear goals to guide their learning, recognize and repair deviations from goals and develop sufficient plans to structure the group process. This indicates that students collaborating in small groups often lack the metacognitive skills to regulate their individual and collective learning in complex open learning environments (Azevedo & Hadwin, 2005; Bannert & Mengelkamp, 2008). During collaborative learning, group members can build on each others’ knowledge and provide feedback on each others’ activities (van Boxtel 2004, Webb, 2009), also on each others’ metacognitive activities (Lin & Sullivan, 2008). Consequently a lack of metacognitive activities does not only hamper the group learning process, but also reduces the development of students’ metacognitive skills in collaboration. Therefore, small groups will continue to face problems regulating their learning.

Scaffolding, providing assistance to a student on as-needed basis, (Wood, Bruner, & Ross, 1976) can support students in tasks they cannot accomplish by themselves (Hmelo-Silver & Azevedo, 2006; Sharma & Hannafin, 2007). Studies found that scaffolding promotes metacognitive activities (Azevedo, Moos, Greene, Winters, & Cromley, 2008; Veenman, Kok, & Blote, 2005) and consequently improves learning achievements, metacognitive knowledge and motivation in individual learning settings (Azevedo & Cromley, 2004; Azevedo & Hadwin, 2005; Land & Green, 2000). The main question addressed in this article is: does scaffolding metacognition in small groups stimulate metacognitive activities and develop metacognitive skills in small groups? This paper extends recent literature by emphasizing the effects of scaffolding on triads’ metacognitive activities. We present the results of an experimental study into the effects of metacognitive scaffolding in an electronic learning environment. First, we elaborate on the role of metacognition in a small group; formulating the mechanisms by which metacognition on the interpersonal plan stimulates metacognitive skills influencing the groups’ metacognitive activities. Next, we discuss how a small group setting influences scaffolding emphasizing the role of peer interaction that amplifies the effects of scaffolding; both of the stimulation of metacognitive activities and consequently enlarging the development of metacognitive skills in group settings. Finally, we explicate how different forms of scaffolds stimulate the groups’ metacognition and enhance metacognitive skills of students in small groups.

Socially shared metacognition

The role of metacognition in small groups is to structure the cognitive processes and the co-construction of knowledge in the activity between individuals and to monitor and control the learning processes of the individual group members. Social metacognition is the process taking place on the interpersonal plane regulating the collective cognitive
The Effects Scaffolding Metacognitive Activities in Small Groups

Different metacognitive activities such as orientation, planning, monitoring, evaluation and reflection regulate the small groups’ collaborate learning (Veenman, Van Hout-Wolters, & Afflerbach, 2006; Zimmerman, 2002). Group dynamics play an important role in both the performance and the development of metacognition in groups (Lin & Sullivan, 2008).

In order to understand how metacognitive activities in small groups develop students’ metacognitive skills; we draw on the socio-cognitive perspective on learning. This perspective offers a framework to analyze how individuals learn in interaction with others emphasizing the individual developments of the students as well as the group development as a result of the interaction on the interpersonal plane (Hadwin & Oshige, 2007; Iiskala, Vauras, & Lehtinen, 2004; Vauras, Iiskala, Kajamies, Kinnunen, & Lehtinen, 2003; Volet, Vauras, & Salonen, 2009). From a socio-cognitive perspective collaborative learning is considered to take place through reciprocal activities between the students on the interpersonal plane (Volet et al., 2009). Consequently, peers play a mediating role in learning of others (Salomon, 1993). The students influence each other in a spiral-like fashion; students contribute knowledge and skills to the social system, which alters the state of the interpersonal plane and elicits new activities from the group members. The activities offer the opportunity to practice skills at the individual level, which subsequently develops the skills and alters the students’ future participation on the small groups’ interpersonal plane. Therefore, individual students appropriate knowledge provided by the social system and in turn contribute with their enhanced participation to the development of the social system (Salomon, 1993; Volet et al., 2009).

In an example, we apply the above described mechanism of development of metacognitive skills in small groups. One student performs a metacognitive activity giving him an opportunity to practice. Additionally, this provides an example for the other group members, which supports the development of their metacognitive skills. The group members can provide feedback and advice on the student’s metacognitive activity. For example, one student monitors the group’s learning activity by stating that he thinks the calculation the group is performing is wrong. Another group member can ask the student why the calculation is wrong, asking the first student to further elaborate on his monitoring. Naturally a prerequisite for this mechanism to be effective is that learners must pay attention to the feedback and perceive it as relevant. Therefore, in case when the group members engage in an interaction around metacognitive discourse in which students co-construct their metacognitive activities, this supports the development of metacognitive skills consequently affecting future collective practices of socially shared metacognition. Accordingly, researchers using a socio-cognitive perspective on learning emphasize the regulating effects of metacognitive interaction on the group’s performance, which develops metacognitive skills and consequently shapes future metacognitive activities in the group.

As mentioned earlier, most students collaborating in small groups have problems to perform metacognitive activities regulating the group learning process. This also hampers the development of students’ metacognitive skills for future participation in collaborative
cognitive activities on the interpersonal plane. Scaffolding can stimulate metacognitive activities in the groups’ interaction and consequently enhance the metacognitive skills within small groups. In the next paragraph we discuss the functioning of scaffolding in small group settings.

**Scaffolding metacognition in social settings**

Scaffolding is defined as providing assistance to a student on as-needed basis, fading the assistance as the competence of the student increases (Wood et al., 1976). The purpose of scaffolding is two-folded: 1) to **support** learners in activities they are unable to accomplish successfully by themselves and 2) to **develop** knowledge and skills needed to perform future tasks (Hmelo-Silver & Azevedo, 2006; Pea, 2004; Sharma & Hannafin, 2007). The purpose of scaffolding metacognition in a social setting is thus to stimulate metacognitive activities on the interpersonal plane and develop metacognitive skills of students needed for future learning during collaboration. Research has mainly focused on how metacognitive scaffolds affect individual students, rather than on how scaffolds influence joint activity. The findings of studies evaluating the use of metacognitive scaffolds showed that scaffolds can support metacognitive activities of individual students (Davis & Linn, 2000; Ge & Land, 2003; Reiser, 2004; Saye & Brush, 2002) and increase the amount of metacognitive activities performed (Azevedo et al., 2008; Veenman et al., 2005). In addition, research also showed that well designed scaffolds can help students to appropriate knowledge and skills sustaining successful application in new situations (Hogan & Pressley, 1999).

In order to be effective, scaffolds in social settings need to stimulate metacognitive activities to regulate the cognitive activity of the group. The group’s activities on the interpersonal plane guide the selection of scaffolding messages (Molenaar & Roda, 2008). Zimmerman’s model (2002) offers a useful theoretical model to determine which scaffolding message can regulate the group’s current learning activities. Metacognitive activities are categorized in preparatory activities (orientation and planning) which are effective at the beginning of an task; executive activities (monitoring and evaluation) effective while working on a task and closing activities (reflection) useful after task completion. For example, when a group starts a learning activity a planning scaffold is appropriate to support the group’s metacognitive activities.

Subsequently, to stimulate planning activities in the group, the scaffold message also has to influence the social interaction between group members (Ge & Land, 2003). Scaffolds focus the collective attention of the group members. Shared attention shapes reciprocal interaction stimulating productive group activities (Barron, 2000, 2003). For example, a planning message focuses the group’s attention on planning of the learning task influencing the activities of the group members and their interaction. Peer interaction is advantageous for learning in a number of ways by providing and receiving explanations, co-constructing ideas, reproving conflicts and negotiating meaning (Ge & Land, 2003). As a result, metacognitive interaction can stimulate the development of metacognitive skills.
Applied on our example; scaffolds focusing on the group’s interaction around planning issues, can support the development of students’ appropriate planning skills to be applied in future learning settings.

To conclude, scaffolding can be applied to social settings to overcome the group’s lack of regulation in complex open learning environments stimulating metacognitive activities on the interpersonal plane. The group setting amplifies the effect of scaffolding facilitating additional interaction around metacognition. Both scaffolding as well as the peer interaction contributes to the development of metacognitive skills equipping students to continue to perform metacognitive activities in the group setting without the support of scaffolding. To further specify how scaffolding stimulates metacognition in a group setting, we need to elaborate on the mechanisms behind scaffolding. In the next section, we describe how structuring and problematizing scaffolds influence students’ metacognitive skills in social settings.

**Different forms of scaffolds**

Reiser (2004) specified two mechanisms of scaffolding to explain how scaffolding functions in detail, namely structuring and problematizing. Scaffolds can simply show examples of regulation, performing part of the groups’ metacognitive activities. These scaffolds structure the groups’ metacognitive activities and stimulate students to elaborate on these issues. An example of a structuring scaffold is to show students an exemplary plan of a task ‘I am going to show you how to introduce yourselves; I am David and I am 12 years old’. Students can consequently elaborate and reformulate the specifications of their group planning activities. Alternatively, scaffolds can problematize metacognitive aspects of the task, posing questions that elicit metacognitive activities. Research shows that problematizing scaffolds such as question prompts elicit individual students’ explanations supporting articulation of their thinking (Chi, Siler, Jeong, Yamuachi, & Hausmann, 2001; Davis & Linn, 2000; King, 1998, 2002). Consequently, problematizing scaffolds trigger students’ metacognitive contributions to the interpersonal plane generating explanations and articulation of their thinking. An example of a problematizing scaffold is asking students ‘How can you plan this task?’ This scaffold elicits planning activities from the students stimulating the group to discuss their collaborative approach to planning the learning task. Thus, the mechanism of scaffolding which is explicated through the form of the scaffolds influences the ways in which metacognition is stimulated.

The different forms of scaffolds additionally address different levels of the social system; resulting in different ways by which the students learn from the scaffolding. Structuring scaffolds contribute metacognitive activities to the interpersonal plane. The examples provided by structuring scaffolds can be appropriated by students and the subsequent students’ interaction discussing their collaborative approach can support further development of metacognitive skills. Referring back to the example of the structuring planning scaffold, students both learn from the planning example in the scaffolding message and elaborate on this example towards the group’s planning strategy.
Problematizing scaffolds address individual students directly stimulating students to form their own metacognitive activities and the question form elicits group discussion. Performing activities as well as giving and receiving explanations results in higher-level thinking and learning (Chi et al., 2001; King, 2002). Applied to the example above, students learn from performing the planning actions and discussing the planning approach followed.

Summarizing the above, different forms of scaffolds stimulate metacognitive activities differently. Structuring scaffolds structure metacognitive activities stimulating metacognition on the interpersonal plane; problematizing scaffolds elicit metacognitive activities of individual student and in turn support group discussion on the interpersonal plane. Thus different forms stimulate metacognitive activities differently, which are intertwined with differently shaping the groups’ interaction consequently influencing the development of metacognitive skills in a different way.

**The present study**

The purpose of this study is to determine the effect of metacognitive scaffolding and the different forms of scaffolding on the groups’ metacognitive activities. To our knowledge there are no studies that systematically researched the effect of scaffolding and specifically of different forms of scaffolds on metacognitive activities in social settings. The main question addressed in this article is: Does scaffolding metacognition in small groups stimulate metacognitive activities and develop metacognitive skills? We report an experiment on the effects of scaffolding and different forms of scaffolds on metacognitive activities of triads in elementary schools. Triads in the scaffolding conditions received scaffolds to support their metacognitive activities; triads in the control condition did not receive scaffolds. Furthermore, two experimental groups received different forms of scaffolds; namely problematizing scaffolds versus structuring scaffolds. Triads in the structuring condition received scaffolds to stimulate metacognitive activities on the interpersonal plane (see examples in appendix 4A, previous chapter) and triads in the problematizing condition received scaffolds addressing individuals to perform metacognitive activities.

Based on the findings of individual studies and on the framework of scaffolding in social settings described above, we expect more metacognitive activities in groups receiving scaffolds than in groups receiving no scaffolds (*Hypothesis 1a: stimulation hypothesis*). Different forms of scaffolds stimulate metacognition and interaction among the students differently. Structuring scaffolds structure metacognition on the interpersonal plane stimulating group interaction, whereas problematizing scaffolds elicit individual students’ metacognitive activities, providing seeds for social interaction and group discussion. Both types of scaffolds positively stimulate metacognitive activities, yet, we expect problematizing scaffolds to have a stronger effect as they explicitly elicit both metacognitive activities and interaction among the group members. Therefore, consistent with the stimulation hypothesis as formulated above, we expect more metacognitive
activities in groups supported by problematizing scaffolds than in groups with structuring scaffolds (*Hypothesis 1b: stimulation hypothesis*).

Students in small groups receiving scaffolds will learn from the scaffolds and engage in more metacognitive social interaction, which develops metacognitive skills which can be used for future learning in small group settings. Therefore, we expect a lasting effect on the performance of metacognitive activities, assuming small groups in the scaffolding conditions to continue to show more metacognitive activities after scaffolding is ceased (*Hypothesis 2a: development hypothesis*). Here we refer to short term development within the small groups in the same learning environment.

Structuring scaffolds show examples of metacognitive activities and support interaction resulting in learners to appropriate metacognitive skills. Problematizing scaffolds elicit metacognitive activities and support interaction and discussion affecting the metacognitive skills. Although both types of scaffolds positively influence the development of metacognitive skills, we expect problematizing scaffolds to lead to more metacognitive interaction and thus have a stronger and sustained impact on metacognitive activities in the groups. Consistent with the development hypothesis as formulated above, we therefore expect that groups supported by problematizing scaffolds continue to perform more metacognitive activities when scaffolding is ceased than groups who are receiving structuring scaffolds (*Hypothesis 2b: Development hypothesis*).

The quantity of the metacognitive activities on the interpersonal plane will be measured during learning analyzing the dialogue of the triads. If the stimulation hypothesis holds, we expect triads who receive scaffolds to perform more metacognitive activities, and the triads in the problematizing condition to outperform the triads in the structuring condition on this aspect. If the development hypothesis holds, we expect groups who receive scaffolds to continue to perform more metacognitive activities after scaffolding is ceased and groups in the problematizing condition to uphold this metacognitive behavior more than groups in the structuring condition.

**Participants**

For this study, we randomly selected 18 triads from 52 triads that participated in a previous study (Molenaar, Van Boxtel & Sleegers, in press). In the original study, 156 students in three schools divided over 6 classes participated. The teachers assigned students to triads (52) based on the principle of heterogeneity; this means that we asked teachers to rate the students as low, middle and high achievers based on their (reading, writing and computer) abilities. Teachers created triads containing one low, one middle and one high achiever. Finally, we randomly assigned the triads to the three experimental conditions, equally divided over the classes: 1. no scaffolds (control group, 16 triads); 2. structuring scaffolds (experimental group 1, 17 triads); and 3. problematizing scaffolds (experimental group 2, 19 triads). The conditions were equally divided over the classes by randomly assigning triads to the conditions within a class, we blocked for effects of classes (Howard, 2006).
For this study, we have randomly drawn three triads (one in each condition) from the original sample from every class. The sample thus consists of 54 students (23 boys and 31 girls) assigned in 6 control triads, 6 triads in the structuring condition and 6 triads in the problematizing condition. The students of this sample were in Grade 4 (9), Grade 5 (27) or Grade 6 (18) of 3 schools for elementary education. With respect to school characteristics; the three schools that participated in our study were comparable; all situated in outer city suburban areas with a white middle class population. As mentioned above we blocked for class effects by ensuring that within every class equal numbers of triads were assigned to the different conditions. This also ensures an equal division of the triads in the different conditions over the different schools. We tested if the number of metacognitive activities in the triad was dependent on the school by calculating the intraclass correlation between the schools. We found an intraclass correlation of 0. Additionally, there was no teacher effect because all classes were taught by the same researcher outside their own classroom in the computer lab. Students were working in triads they had never worked in the exact same combination before. Because all triads performed the same task, there were no deviations in task characteristics among the triads.

Finally, we did not measure the metacognitive knowledge or skills of the individual students to create the triads, because offline measures of metacognition are not or low correlated with actual metacognitive performance (Veenman, Wolters & Alferbach, 2006). This is due to two problems with offline measurements, first they ask students to make a judgment of their metacognitive activities without providing a contextual reference and second off line measures ask students to make a general judgment about their abilities.

Treatment: The scaffolding system and the conditions

The e-learning environment used in this study is called Ontdeknet. It focuses on supporting students in their collaboration with experts (Molenaar, 2003). Ontdeknet embeds the design elements of complex open learning environments in three aspects: constructive learning assignments, a situated environment and collaborative learning. Constructive learning assignments come to the fore in the self-initiating role the students play with respect to the learning strategies and topics to be learned. Teachers only provide the overall assignment and students select their own learning goals and their learning strategies to pursue these goals. Students thus have much control over their own learning and are encouraged to self-regulated learning.

The role of the experts is to support the students in acquiring their goals through providing information and expertise. Situated environment is related to this role of the experts. The information given by the experts concerns their professional or personal knowledge and experiences. The language used by the experts is related to their expertise, and their examples, reasoning and explanations reflect their thinking as an expert about the topic (Ericsson & Charness, 1994). The experts’ contributions are edited for its value and relevance for students by the editor of Ontdeknet. Collaborative learning is implemented at
two levels: students collaborating with an expert in a virtual environment and with each other in small groups behind the computer.

The computerized scaffolds were dynamically integrated into the learning environment. An attention management system was used to determine when to send which scaffold to the learners. Attention management systems capture the attention focus of the students (Roda & Thomas, 2006). The attentive system research aims at defining the factors and determining the likely utility of given information for a given user in a given context and the costs associated with presenting the information in a certain way (Roda & Nabeth, 2007). The utility of attentive systems for learning is to detect the attentional focus of the student and interpret this information to support the learning process (Molenaar & Roda, 2008). Our system monitored the students’ attention focus and based on this information supplies the scaffolds. The attentional focus was monitored at three levels: the input level, the reasoning level and the intervention level. The input level collected information about the students’ attention from the students’ environment. Currently, input information was derived from the keyboard strokes, mouse movements and event information about the students’ activities in the e-learning environment. The reasoning level determined what was in the focus of the student based on the event information and the active task of the student. Based on this diagnosis of the students’ attention information a scaffold was selected that can be useful for the learner. Finally, the intervention level determined how the scaffold is communicated to the learner. Ontdeknet used a three-dimensional virtual agent powered by Living Actor technology for the delivery of scaffolds. The scaffolds were shown in text balloons and could be heard as spoken messages through the computer’s audio output. The messages were accompanied by the agent’s animations (e.g. movements of the agent’s hands) and emotions (e.g. smile on the face of the agent). The systems reasoning system was validated in extensive studies ensuring the functioning of this component with a wizard of OZ design and test runs of the systems within schools (Molenaar & Roda, 2008).

The total duration of the experiment was 8 lessons of 1 hour. In the first lesson, the students were given instructions about the task and the electronic learning environment and the last lessons was juste to fill in questionaires. All students received the same instructions and all triads spent the same time working on the task (6 hours). In 6 lessons the triads worked on a task called “Would you like to live abroad?” The goal of the task was to explore a country of choice (New Zealand or Iceland), write a paper on the findings and decide if they would like to live in this country. The triads worked on one computer and had access to an inhabitant of the country. They could consult the expert by asking questions and requesting information about different topics about the country that they were interested in. In the expert section, the requested information about the country was written by the expert and questions were answered in a forum.

The task to write a paper about the country was preceded by 4 sub-tasks: introducing the group, writing a goal statement, selecting a country and specifying topics of interest in a mind map to further support the collaboration with the expert. 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 triads in both experimental scaffolding conditions received scaffolds supporting their metacognitive activities at the same instance in their learning process during the first two lessons. The scaffolds were delivered at times when metacognitive activities are generally executed in the learning process based on Zimmerman’s model for self-regulated learning (Zimmerman, 2002). As mentioned above, the scaffolding system determined the appropriate instance to send a scaffold based on the students’ attention focus. The scaffolds were triggered by the system in relation to the following changes in the attention focus of the students. Orientation activities should be performed just before selecting a task; thus at sub-task selection triads received a scaffold to orientate on the sub-task. Planning should be done just before starting a task; therefore planning scaffolds were implemented just before execution of the sub-task. Finally, monitoring should be performed during and after execution of the task, upon saving the sub-task triads were shown a scaffold prompting them to monitor (Molenaar, van Boxtel, Sleegers & Roda, 2011). For each sub-task three types of scaffolds were implemented: orientation, planning and monitoring scaffolds. Students in the scaffolding conditions received a minimum of 12 scaffolds in each condition (see Appendix 4A for an overview of all scaffolding messages).

The triads in the structuring condition (experimental group 1) received scaffolds in the structuring form, which consisted of direct support to their metacognitive activities on the interpersonal plane. The triads in the problematizing condition (experimental group 2) received scaffolds in the problematizing form which were designed to elicit individual students’ metacognitive activities and explanations. The triads in the problematizing condition were obliged to answer the agent’s questions in an answer box on the screen (see figure 7) for an example of both forms of scaffold. Screenshots in 4A show how the messages are integrated into the electronic learning environment. Table 7 shows the messages of the orientation, planning and monitoring scaffolds in structuring and in problematizing form for the introduction task (Appendix 4A contains all scaffolding messages).

Figure 7. An example of a structuring and problematizing scaffold.
Table 7. Examples of structuring and problematizing scaffolds for the introduction task.

<table>
<thead>
<tr>
<th>Situation</th>
<th>Structuring scaffold</th>
<th>Problematizing scaffold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation on introduction</td>
<td>Before we start, I would like to know who you are, please introduce yourselves.</td>
<td>Why are you going to introduce yourselves?</td>
</tr>
<tr>
<td>Planning of introduction</td>
<td>I am going to show you an example of how to introduce yourselves: I am David, I am 12 years old and like to play games on the internet.</td>
<td>How are you going to introduce yourselves?</td>
</tr>
<tr>
<td>Monitoring of introduction</td>
<td>Thank you, I will send your introduction to the expert.</td>
<td>Did you introduce yourselves as planned?</td>
</tr>
</tbody>
</table>

Finally, the triads in the control group did see the virtual agent, but did not receive any form of metacognitive support from the agent. The agent was included in the interface to prevent a Hawthorne effect, implicating that the sole presence of the agent could influence the student activities without the actual scaffolding (Franke & Kaul, 1978).

Measurements

The discourse of all triads was audio-taped using voice-recorders. We coded the transcribed protocols of each lesson. The unit of analysis was the speakers’ turn. Mutually exclusive and exhaustive categories were used, which entails that every turn was coded and coded with only one main category code and one subcategory code. Table 8 shows an overview of the main categories. The categories cognitive activities, metacognitive activities, off task activities, not codable activities and teacher activities were derived from the coding scheme of Veldhuis-Diermanse (2002). Additionally, two types of activities were added: relational activities specific for the group setting and procedural activities specific for our learning environment.

Table 8. Main categories of our coding scheme.

<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>

The category metacognitive activities includes turns that deal with the regulation of cognitive activities, thus the controlling and monitoring of these activities on the interpersonal plane. The category cognition contains turns about the content of the task and
elaboration on this content. Relational turns deal with social interaction between students in the triad. Procedural turns support procedures using the electronic learning environment. The main subcategory metacognitive activity was coded further for six different subcategories: orientation, planning, monitoring, evaluation and reflection which were derived from the coding scheme of Meijer, Veenman, & van Hout-Wolters (2006) for metacognitive subcategories. Previously reported low numbers of execution activities lead to the removal of this subcategory in our coding schema.

Within each subcategory, different activities are combined as specified in Table 9. Orientation utterances include turns about orientation on prior knowledge, task demands and feelings about the task. Planning utterances deal with planning of the learning strategies used for a particular task. Monitoring of the learning process deals with turns related to checking the progress and the comprehension of the task. Evaluation utterances deal with the evaluation of the learning process and content and finally reflection elaborates on the learning process.

Table 9. Subcategories of metacognitive activities

<table>
<thead>
<tr>
<th>Subcategory</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td>Orientation on prior knowledge, task demands and feelings about the task</td>
<td>What do we need to do? Do you know what a learning goal is?</td>
</tr>
<tr>
<td>Planning</td>
<td>Planning of the learning process, for instance, sequencing of activities or choice of strategies</td>
<td>How are we going to do this? Now we are going to ask questions.</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Monitoring of the learning process: checking progress and comprehension of the task.</td>
<td>I do not understand You are doing it wrong Wait, please just leave it like that</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Evaluation of the learning process; checking of the content of the learning activities.</td>
<td>We posted a good question These are the most important issues</td>
</tr>
<tr>
<td>Reflection</td>
<td>Reflection on the learning process and strategies through elaboration on the learning activities.</td>
<td>Let me think, this is more difficult than I thought Why do we have the most difficult task?</td>
</tr>
</tbody>
</table>

For each group and for each lesson we calculated the quantity of metacognitive activities and of the sub-activities orientation, planning, monitoring, evaluation, and reflection. We cumulated these numbers to the total quantity over all the lessons. To determine the reliability, two raters independently coded two randomly selected protocols (2500 turns). We used Cohen’s Kappa to determine the inter-rater agreement. There was an excellent (Fleiss, 1981) agreement for the main categories: the kappa was $K=0.92$. The kappa was highest for the category metacognitive activities $K=0.94$ and lowest for category non-codable $K=0.82$. There also was an excellent agreement within the sub-metacognitive scale with an overall kappa of $K=0.92$. The kappa was the highest for orientation $K=0.94$ and lowest for planning $K=0.77$. 
Analysis

As mentioned earlier, the purpose of our study is to determine the effect of metacognitive scaffolding and the different forms of scaffolding on the groups’ metacognitive activities. The focus of our study is thus on the stimulation and development of metacognition in small groups through scaffolding. As a consequence all analyses were done at the triad level and we therefore did not pay attention to individual differences between students or effects of metacognitive group activities on individual performances.

To assess the metacognitive activities of triads, we used discourse analysis. The total dataset entails 108 hours of lessons and 51,339 utterances. To test the stimulation hypothesis, we examined the effects of scaffolding on the quantity of metacognitive activities performed by triads. The development hypothesis was tested by examining the quantity of metacognitive activities performed after scaffolding has been ceased (lessons 3 until 6). There was no significant difference in total utterances between the control condition (mdn = 2633) and the scaffolding conditions (mdn = 3122; U = 32; p = 0.75 n.s.) nor between the problematizing condition (mdn = 3223) and the structuring conditions (mdn = 3122; U = 16; p = 0.82 n.s.). We therefore used in our analysis frequencies of metacognitive activities. Although the distributions of the conditions were similar, but the sample was not normally distributed, we used a Mann-Whitney test to evaluate the hypotheses.

The first test was between the control condition and the scaffolding conditions to assess the effect of scaffolding. The second test was between the problematizing condition and the structuring condition to assess the effect of the form of scaffolding. 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. To further determine the effects on subcategories we followed the same procedure. There were too few reflection turns (0.08% of all metacognitive turns) to include them in the analysis.

Results

Stimulation of metacognitive skills: the activation of metacognitive activities during scaffolding

The Mann-Whitney test showed an effect of scaffolding on the frequency of metacognitive activities on the interpersonal plane: the experimental group (mdn = 687) outperformed the control group (mdn = 400) significantly (U=17; p<0.05 (one sided); r=0.40). These findings suggest that scaffolding had a medium to large effect on the quantity of metacognitive activities.

With regard to the effects of scaffolding on the separate metacognitive sub-activities (orientation, planning, monitoring and evaluation), the results revealed that there is a significant difference between the triads in the experimental and the triads in the control condition with respect to the quantity of the metacognitive sub-activities they perform. The
triads supported by scaffolds performed more orientation activities (mdn= 22) compared to the control group (mdn= 14; U =17, p=0.04 (one sided), r= 0.42). Also more monitoring activities occurred in the dialogue of the triads supported by scaffolds (mdn= 312) compared to the control group (mdn=210; U =14; p < 0.05(one sided), r=0.49). Furthermore the results indicated a trend in the expected direction; the triads in the experimental condition performed more planning activities (mdn= 238) than the triads in the control group (mdn=117; U =20.5; p > 0.05 (one sided), r=0.34) and more evaluation activities (mdn=77) compared to the triads in the control condition (mdn=55); (U=23; p>0.05; r= 0.28). Figure 8 shows an overview of the mean frequencies for the separate metacognitive sub-activities.

![Figure 8. The mean frequency of metacognitive sub-activities comparing the control group and the scaffolding conditions.](image)

In addition to examining the effect of scaffolding on metacognitive activities between the experimental condition and control condition, we also examined the effect of different forms of scaffolding on the amount of metacognitive activities triads performed. In order to assess this effect, a Mann-Whitney test was performed comparing the differences between the problematizing condition and the structuring condition. The results showed that student dialogues in the problematizing condition (mdn=766) did not contain significantly more metacognitive activities than dialogues of the structuring group (mdn = 624; U=14; p>0.05, r= 0.19). We also did not find significant effects of forms of scaffolding on the metacognitive sub-activities performed by triads in the different experimental groups. Figure 9 provides more information and shows an overview of the different metacognitive activities performed by the different conditions. All trends are in the expected direction.
The effects of scaffolding on the development of the metacognitive activities on the triads’ interpersonal plane after scaffolding ceased were analyzed with a Mann-Whitney test. The results showed a significant lasting effect of scaffolding on the frequency of metacognitive activities on the interpersonal plane. The triads in the experimental condition who received scaffolds showed significantly more metacognitive activities when scaffolding has ceased (mdn 369) than the triads in the control group (mdn = 241; U=15.5; p<0.05 (one sided), r=0.45). These findings suggest that scaffolding can have a medium to large effect on the development of metacognitive activities even when scaffolding has been ceased.

Effects of scaffolding on the development of metacognitive skills found comparing the control condition and the experimental condition, could not be found when comparing the structuring condition to the problematizing condition. The results of the Mann-Whitney test between these two experimental conditions showed that student’s dialogues in the problematizing condition (mdn=417) did not contain significantly more metacognitive activities than the student’s dialogues of the structuring group (mdn = 321; U=15; p>0.05, r= 0.14) when scaffolding has ceased.

Figure 9. The mean frequency of metacognitive sub-activities comparing the structuring condition to the problematizing condition. (overall triads and lessons)

Development of metacognitive skills; activation of metacognitive activities after scaffolding ceased

The effects of scaffolding on the development of the metacognitive activities on the triads’ interpersonal plane after scaffolding ceased were analyzed with a Mann-Whitney test. The results showed a significant lasting effect of scaffolding on the frequency of metacognitive activities on the interpersonal plane. The triads in the experimental condition who received scaffolds showed significantly more metacognitive activities when scaffolding has ceased (mdn 369) than the triads in the control group (mdn = 241; U=15.5; p<0.05 (one sided), r=0.45). These findings suggest that scaffolding can have a medium to large effect on the development of metacognitive activities even when scaffolding has been ceased.

Effects of scaffolding on the development of metacognitive skills found comparing the control condition and the experimental condition, could not be found when comparing the structuring condition to the problematizing condition. The results of the Mann-Whitney test between these two experimental conditions showed that student’s dialogues in the problematizing condition (mdn=417) did not contain significantly more metacognitive activities than the student’s dialogues of the structuring group (mdn = 321; U=15; p>0.05, r= 0.14) when scaffolding has ceased.
Some illustrations

In order to better understand the effect of scaffolding on the development of metacognitive activities in the triads, figure 10 illustrates the mean frequencies of the different metacognitive activities in the different conditions over time. This figure shows that orientation only occurs more frequently in the problematizing condition when students received orientation scaffolds. After the scaffolding ceases the orientation activities immediately fall back, seemingly not yielding any learning effects.
With respect to planning and monitoring, both problematizing and structuring scaffolds stimulated the occurrence of these activities. The problematizing conditions continue to show more planning and monitoring activities in lesson 3 compared to the structuring and control conditions after which the patterns become comparable. Thus during the third lesson there seems to be a stronger learning effect of problematizing scaffolds compared to structuring scaffolds. Finally, we did see an effect of scaffolding on the evaluation activities even though students did not receive scaffolds directed at evaluation activities.
Triads in the structuring condition show an increase during lesson 2. Triads in the problematizing condition show a higher frequency throughout all the lessons. This could be explained by the high interdependency between the different metacognitive activities (Veenman & Spaans, 2005). For example, a detailed learning plan supports the students to effectively monitor the learning progress, checking their proceedings and supports evaluative actions to correct failures and misunderstandings. This interdependency could entail that scaffolding particular metacognitive activities on the interpersonal plane (i.e. orientation, planning and monitoring) can also influence metacognitive activities that are not supported by scaffolds (evaluation and reflection).

**Conclusion and discussion**

Research has shown that students collaborating in small groups have difficulties with regulating their learning in a complex open learning environment, due to a lack of metacognitive activities. In order to stimulate metacognitive activities to enhance the collective cognitive activity and develop metacognitive skills for future learning, scaffolding of metacognitive activities is needed. In this study an experiment was performed comparing a control group to the experimental group that received scaffolds. Our first goal was to understand the effects of metacognitive scaffolding on the quantity of metacognitive activities in small groups. In addition, the effects of different forms of scaffolds on the metacognition activities in small groups were tested comparing the experimental triads in two different experimental conditions: triads receiving structuring scaffolds versus triads receiving problematizing scaffolds. Our second goal was to determine the lasting effects of scaffolding on metacognitive activities in small groups after scaffolding is ceased and to establish the differential effects of problematizing versus structuring scaffolds on the groups’ metacognitive activities. We tested the hypotheses by analyzing the discourses of triads’ aged 10 to 12 in three different schools in the Netherlands.

The results of the discourse analysis showed that metacognitive scaffolding had a significant positive effect on the quantity of metacognitive activities performed by triads on the interpersonal plane. The analysis of the sub-activities also showed a significant effect for orientation and monitoring activities and a trend in the expected direction for planning and evaluation. These findings confirmed our stimulation hypothesis: scaffolding supported triads to engage in more metacognitive activities. With respect to the effect of different forms of scaffolds on the metacognitive activities; we predicted that problematizing scaffolds elicit more metacognitive activities than structuring scaffolds. This expectation was based on the combination of two aspects; the direct activation of students’ metacognitive activities and the anticipated stronger effect on the interaction in the group of problematizing scaffolds. This hypothesis was not confirmed, yet the direction of the results was as expected. These results suggest that scaffolding can increase metacognitive activities on the interpersonal plan, yet we did not find differentiating effects of the different forms of scaffolds.
The development hypothesis predicted that scaffolds have a positive effect on the metacognitive skills revealed by the amount of metacognitive activity performed after the scaffolding was ceased. This hypothesis was also confirmed; the triads receiving scaffolds remained to perform more metacognitive activities after the scaffolding had stopped than the triads in the control group. This supports the expectation that metacognitive activities on the interpersonal plane contribute to the development of the individual metacognitive skills of students leading to a lasting effect on metacognitive activities. These findings co-collide with findings from another study we conducted on the effect of scaffolding on learning outcomes; students receiving scaffolds scored significantly higher on individual metacognitive knowledge than students that did not receive scaffolds (Molenaar, van Boxtel & Sleegers, 2011). This thus confirms the following mechanism; the scaffolds stimulate metacognition which leads to an increase in metacognitive activities in interaction between the group members which supports the development of individual metacognitive skills resulting in more metacognitive activity in the triad. The form of the scaffolds, however, did not affect the performance of metacognitive activities after scaffolding was ceased, but again the trend was in the anticipated direction.

A possible explanation for the lack of a significant difference between the two different forms of scaffolds could or might be the limited intensity of scaffolding, the students only received 12 different scaffolds during the first two hours on the task. This intensity is enough to make the distinction between no scaffolding and scaffolding but not to make the more subtle distinction between the different forms of scaffolding. Additionally, it is possible that the form of the scaffold made no difference with respect to triggering metacognitive activities and had no differential influence of the groups’ interaction. However, our previous findings with respect to the effects of different forms of scaffolding on individual learning outcomes did show that students gained more metacognitive knowledge on an individual test taken after the study (Molenaar et al. 2011). We anticipated that these results could be explained by the quantity of metacognitive activities performed in the triads; however this analysis shows this is not the case. To complicate this case, we also found that the groups supported with problematizing scaffolds wrote papers with significantly higher quality and scored significantly higher on the transfer of domain knowledge than students in the structuring condition (Molenaar et al., 2011). These results demand for an explanation; why do problematizing scaffolds yield more metacognitive knowledge than structuring scaffolds even though they do not stimulate more metacognitive activities? There are a number of viable explanations; first, the qualitative differences in metacognitive activities indicating that some metacognitive activities are better than others and thus have more effect on the development of metacognitive skills. Second, the interaction around metacognitive activities caused by the different forms of scaffolds could lead to different learning results; more transactive interaction in which learners build more on each other’s contributions are known to increase cognitive learning results (Teasley, 1997, Weinberger & Fischer, 2006) and might also increase the development of metacognitive knowledge in small groups. Third; in line with the interdependence of metacognitive activities the answer could be sought in
different combinations of the metacognitive activities (the optimal mix) and the positioning of the metacognitive activities over time. In future work these directions will be further explored. Finally, the problematizing scaffolds could have been more successful at capturing students’ attention, because students were requested to fill in the answer box.

The main limitation of this study was the small sample size; which should caution the reader in generalizing the result presented. Furthermore, there could be metacognitive activities occurring in the group which are not verbalized by the group members. This can occur if there is non-verbal communication among the group members or if one group member is working individually not verbalizing nor sharing his process with the other group members. Additionally, it could be argued that some metacognitive activities are not explicit, but implicit in the occurrence of higher cognition (Veenman et al., 2006). For these reasons the measurement of metacognitive activities is not exhaustive for all metacognitive activities occurring within the triads. Another limitation is the specific group of participants, namely students from elementary schools, that was used in the experiment. We should be careful in generalizing the results to older students due to the developmental differences in metacognitive knowledge and skills. Finally, the positive effect found may also be caused by the fact that the scaffolding agents were new and interesting for the students participating in the study. However, we do think that this possible short-term additional effect will not sustain over time, thereby reducing the effect of scaffolding during and after the experiment.

Despite these limitations, our main conclusion is that metacognitive scaffolding of small groups in complex open learning environments is successfully in stimulating metacognitive activities and supporting the development of metacognitive skills in the triads. The form of scaffolds does not significantly influence activation of metacognitive activities on the interpersonal plane, however earlier results did show significantly more individual metacognitive knowledge resulting from problematizing scaffolds. This leaves a puzzle to be unraveled in future work. This study contributes to the scientific body of knowledge about the effects of metacognitive scaffolding in small group settings. On a practical level the results can help teachers understand how to support the regulation of small groups of students in complex open learning environments.

Acknowledgements

This research was supported by grants from the National Scientific Organization of the Netherlands (NWO) 411-04-102 and from the European Commission under the FP6 Framework project Atgentive IST 4-027529-STP.