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

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Young students in elementary education often have problems effectively controlling and monitoring their learning in complex computer-based environments. In the Atgentive project, we developed a computerized scaffolding system to support students’ self-regulated learning to overcome that problem. This thesis addresses the research question: What are the effects of computerized scaffolding of self-regulated learning on learning of collaborating students? To answer this question seven sub-questions were formulated, which were answered in seven chapters in this thesis. The questions and their answers are grounded in the theoretical constructs: self-regulated learning, scaffolding and the socio-cognitive perspective on collaborative learning.

Students’ ability to steer and regulate their learning is considered important for learning in complex computer-based learning environments. Self-regulating learners are those learners who successfully use cognitive activities (read, process, elaborate) to study a topic, control and monitor their learning with metacognitive activities (orientate, plan, monitor and evaluate their actions) and are able to motivate themselves (Zimmerman, 2002, Azevedo et al., 2008, Winne & Hadwin, 2010). Students’ self-regulated learning can be supported with scaffolding, which refers to providing assistance to a student on an as-needed basis, fading the assistance as the competence of the student increases (Wood, Bruner & Ross, 1976). Students often learn collaboratively in complex computer-based environments. Under the right circumstances collaborative learning enhances group performance and individual learning (Cohen, 1994; Johnson & Johnson, 1999; Lou, 2001; Slavin, 1996; Dillenbourg et al., 2009). In this thesis, we use the socio-cognitive perspective on collaborative learning to explain how individuals learn in interaction with others. This perspective emphasizes the student’s individual development as well as the group development as a result of the collaboration between group members (Hadwin & Oshige, 2007; Iiskala, Vauras, & Lehtinen, 2004; Vauras, Iiskala, Kajamies, Kinnunen, & Lehtinen, 2003; Volet, Vauras, & Salonen, 2009).

In part I, the conceptual framework that supported the development of the scaffolding system AtgentSchool is described, as well as the results of the first study on scaffolding self-regulated learning. Chapter 1 describes the theoretical foundation and rationale for the design of our scaffolding system. This chapter specifies how an attention management system can support dynamic scaffolding for self-regulated learning. Attention management systems capture information from the students’ environment about the students’ attentional focus. This information is interpreted to select scaffolds for the learners. The essential elements for selecting appropriate scaffolds are diagnosis, calibration and fading. The appropriate scaffold is selected from an intervention model with scaffolds that support the components of self-regulated learning, namely cognition,
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metacognition and motivation. Based on the test-runs, we concluded that the system functioned according to the conceptual framework.

Chapter 2 reports on the results of the first study that assessed the effects of scaffolding of self-regulated learning on the groups’ performance, perception of the learning environment and individual students' acquisition of domain knowledge. This study was performed in the Czech Republic with students aged 11 years, who worked collaboratively in dyads on a task in AtgentSchool. Students in the scaffolding condition (n=56) were supported with computer-generated scaffolds and students in the control condition (n=54) did not receive scaffolds. The scaffolds were dynamically adjusted to the students’ progress with the attention management system. The scaffolds supported students’ metacognitive and cognitive activities. We found that scaffolding had a positive effect on the students’ group performance, but did not affect individual students’ domain knowledge. The repeated measurement of perceptions of the learning environment showed that students in the experimental condition were more positive about their teachers and their peer-collaborators than students in the control condition. With respect to their perception of the software and the 3D embodied agent delivering the scaffolds, we found a stronger decrease in appreciation over time in the scaffolding condition compared to the control condition.

Part II focuses on the effects of metacognitive scaffolding and different forms of scaffolds (structuring and problematizing scaffolds) on learning. In chapter 3, we discuss the effects of metacognitive scaffolding and different forms of scaffolds on the groups' performance and individual students' domain and metacognitive knowledge. This study was performed in the Netherlands with students aged 9 to 12 years who worked collaboratively in triads on a task in AtgentSchool. In an experimental design the two experimental groups receiving scaffolds were compared with a control group (n=48). The experimental groups differed in the form of scaffolding used: structuring scaffolds which entailed context-specific examples (n=51) vs. problematizing (n=57) scaffolds which were context-specific questions. We analyzed the effects of metacognitive scaffolding and of different forms of scaffolds on the learning outcomes at group and individual level. The results showed no effect of scaffolding on group performance nor on acquired individual domain knowledge and a significant effect on acquired individual metacognitive knowledge. Students in the scaffolding condition gained higher scores on the metacognitive knowledge test than students in the control condition. With respect to the effects of different forms of scaffolds, we found a small significant effect on group performance, on transfer of individual domain knowledge and on the individual metacognitive knowledge acquired. Students receiving problematizing scaffolds gained better learning results than students receiving structuring scaffolds and students in the control group.

In order to explain the differential results of different forms of scaffolds, we investigated the effect of scaffolds on the groups' metacognitive activities on the data set
from the second study. This study, described in Chapter 4, examined the effects of scaffolds on groups’ metacognitive activities in a complex computer-based learning environment. We used discourse analysis to analyze students’ metacognitive activities. Due to the labor intensiveness of discourse analysis, we only used a randomly drawn subsample from the second study: 6 control groups (n=18), 6 structuring groups (n=18) and 6 problematizing groups (n=18). We analyzed the effects of scaffolding and the different forms of scaffolds on the amount of metacognitive activities of triads, making a distinction between the two lessons triads received scaffolds and the four lessons they did not. The results showed that scaffolding had a significant effect on metacognitive activities; triads receiving scaffolds performed significantly more metacognitive activities. Additionally, scaffolding also had a significant development effect; triads continued to show more metacognitive activities after the scaffolding 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 than triads receiving structuring scaffolds.

Chapter 4 did not explain the differential learning results of different forms of scaffolds. To further unravel this puzzle, we analyzed the mediated role of metacognitive activities on the effects of scaffolding and different forms of scaffolds on students’ learning. The findings of these analyses are described in chapter 5. Multivariate, multilevel analysis of the 51,339 conversation turns from the 54 students from the second study showed once again that scaffolding had an effect on students’ learning. Students receiving structuring or problematizing metacognitive scaffolds displayed more metacognitive knowledge than students in the control group. We found that students’ own metacognitive activities mediated the effects of scaffolding and that increased metacognitive activities supported students’ metacognitive knowledge. Moreover, students that were engaged in proportionately more cognitive activities or fewer off-task activities also outperformed other students on the metacognitive knowledge test. In this sample, contrary to the findings in chapter 3, problematizing scaffolds did lead to more domain knowledge and again students’ own metacognitive activities mediated the effects of the problematizing scaffolds. Moreover, students in the problematizing condition that were engaged in more cognitive activities or whose group mates used more relational activities had greater domain knowledge acquisition than other students. We proposed that the differential effects of problematizing scaffolds could be explained by qualitative differences in the students’ metacognitive activities. This proposition was explored in part III.

Part III focuses on how students collaboratively regulated their learning and investigates the effects of scaffolding on students’ metacognitive activities embedded in interaction. Chapter 6 investigates how metacognitive activities were embedded in interaction between the group members during collaborative learning. Research indicates that the quality of cognitive activities is positively influenced by transactive interaction in which group members relate to and engage in each other’s contributions (Roschelle, 1996, Teasley, 1997; Weinberger, Stegemann & Fischer, 2007). We examined whether
metacognitive activities embedded in different types of interaction were more likely to facilitate the group process and the provisional role of shared attention on interaction. We analyzed 996 metacognitive episodes embedded in the interaction of 6 triads from the control condition (n=18) collaborating on a research task in a computer-based learning environment. The findings show that metacognitive activities in small groups occurred in four different types of interaction which were accompanied with an increasing level of transactivity, namely ignored, accepted, shared and co-constructed among the group members. Shared attention did indeed support more transactive interaction. Moreover, metacognitive activities embedded in more transactive interaction were more likely to facilitate the group process than those embedded in less transactive interaction. These findings confirm that interaction between the group members can positively influence the quality of metacognitive activities and that in collaborative settings it is important to look at how metacognitive activities are embedded in interaction.

Chapter 7 explores the effect of computerized scaffolding with different scaffolds (structuring vs. problematizing) on the way metacognitive activities were embedded in the interaction among group members during collaborative learning. In this study, we investigated the different types of interaction around metacognitive activities of 18 triads (6 control groups (n=18) and 12 scaffolding groups (6 structuring (n=18) and 6 problematizing (n=18)). We found that groups receiving scaffolding showed significantly more co-constructed metacognitive activities than groups in the control condition. Groups receiving problematizing scaffolds showed significantly less ignored and more co-constructed metacognitive activities than groups receiving structuring scaffolds. These findings indicate that scaffolding positively influenced the way metacognitive activities were embedded in the interaction between group members. Moreover, these findings seem to explain the differential learning effects of different forms of scaffolds. Future research should therefore consider how to design scaffolds that support metacognitive activities embedded in more transactive interaction.

Reflecting on the goal of the AtgentSchool computer program, namely to support small groups in complex computer-based learning environments to enhance the regulation of their learning, the findings show that it succeeded in stimulating students’ metacognitive activities and knowledge. Although this seemed to support group performance, it did not affect individual students’ domain knowledge. Moreover, we found that problematizing scaffolds were superior to structuring scaffolds, generating better effects on learning. Our findings contributed to our understanding of how scaffolding in collaborative settings influenced learning. First, small groups receiving metacognitive scaffolds performed more metacognitive activities and continued to show more metacognitive activities after scaffolding was stopped. Second, the effect of scaffolding on students’ metacognitive knowledge was mediated by these metacognitive activities. Third, students’ own activities influences their learning significantly, whereas other students’ activities had less impact, though there is an exception in the case of other students’ relational activities. Fourth, different forms of scaffolds can have differential effects on students’ transactive
interaction. Finally, qualitative differences in the way activities are embedded in interaction (more or less transactive) seemed to influence students’ learning from scaffolding.

Our research findings suggest that scaffolding in small groups is strengthened by the interaction among the group members. This means that scaffolds could be designed in ways that are more attuned toward eliciting students' interaction. Future research needs to test the proposition, but it seems that scaffolding during collaborative learning could be a powerful mechanism to enhance students’ metacognitive knowledge and skills.