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

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2 Dynamic Scaffolding of Self-Regulated Learning

Abstract The aim of this study is to test the effects of dynamically scaffolding self-regulated learning of middle school students working in a computer-based learning environment. Students in the scaffolding condition (N=56) are supported with computer-generated scaffolds and students in the control condition (N=54) do not receive scaffolds. The scaffolds are dynamically adjusted to students’ progress with an attention management system. The scaffolds support students’ metacognitive and cognitive activities. We analyzed the effects of dynamic scaffolding on students’ learning and on their perception of the learning environment. We found that scaffolding has a positive effect on the students’ learning performance, but did not affect 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 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 of perception over time in the scaffolding condition compared to the control condition.

Keywords ∙ Self regulated learning ∙ Dynamic scaffolding ∙ Attention Management Systems ∙ Middle school

Introduction

Self-regulation is important for learning in complex Computer-Based Learning Environments (CBLE’s), such as hypermedia and computer based learning environments (Azevedo & Hadwin, 2005, Bannert & Mengelkamp, 2008). Students have to define their own learning goals and form a strategy to obtain these goals (Kalyuga, Chandler & Sweller, 2001; Kirschner, Sweller & Clark, 2006). In complex computer-based learning environments students are often incapable of adequately regulating their learning (Azevedo, Moos, Johnson & Chauncey 2010; Azevedo & Hadwin, 2005). Scaffolding can support students in tasks they cannot accomplish by themselves by providing assistance when needed (Hmelo-Silver & Azevedo, 2006; Sharma & Hannafin, 2007; Wood, Bruner, & Ross, 1976). Studies found that scaffolding fosters self-regulated learning and consequently improves students’ learning and motivation (Azevedo & Cromley, 2004; Azevedo & Hadwin, 2005; Land & Greene, 2000).

The effectiveness of scaffolding provided by human tutors has recently stimulated the development of computer-based scaffolding systems supporting self-regulated learning such as Metatutor (Azevedo Johnson, Chauncey, 2010) and Atgentive (Molenaar, Van Boxtel, Sleegers & Roda, 2011). These systems are inspired by effective human tutors who determine scaffolding needs through diagnosis of students’ behavior and appropriately reduce scaffolds when students’ competences increase (Chi, Siler, Jeong, Yamauchi & Hausmann, 2001; Wood, Bruner & Ross, 1976). Most computerized scaffolding systems, however, enact scaffolds at predetermined time intervals. Therefore the scaffolds are not adjusted to the students’ progress, which compromises learning (Azevedo, 2004). A solution to this problem is to automatically monitor students’ behavior and consequently adjust scaffolds accordingly. Therefore, we need a system that tracks and traces students’ activities, diagnoses current behavior, and then selects the scaffolds that foster self-regulated learning (Azevedo et al, 2010, Molenaar & Roda, 2008).

In our study, we used an attention management system to attain dynamic scaffolding (Molenaar et al., 2011). The aim of this study is to assess the effects of dynamic scaffolding on middle school students’ learning and their perception of the learning environment. This analysis allows us to identify how the AgtentSchool system we developed supported students’ self-regulated learning. We will start with a short discussion how an attention management system can support dynamic scaffolding. Then we will elaborate on studies assessing the effects of scaffolding on learning and motivation.

Computerized dynamic scaffolding

Scaffolding is defined as providing assistance to a student as-needed, fading the assistance when the competence of the student increases (Wood, Bruner & Ross, 1976). Within the scaffolding paradigm, a distinction can be made between different types of scaffolding, namely static and dynamic scaffolding (Molenaar & Roda, 2008; Puntambekar & Hübscher, 2005). Static scaffolding is constant over time and the same for all students (e.g.
one may provide a list of instructions that helps users to perform a learning activity). Whereas static scaffolds do not adjust to individual students’ progress, dynamic scaffolds do. Dynamic scaffolding analyzes the students’ behavior after which an appropriate scaffold is selected (i.e. one can monitor the progress of the student and provide scaffolds when needed in the learning process).

The latter form of scaffolding use diagnosis, calibration and fading to select the right scaffold for a particular student in a specific situation. As described above human tutors perform dynamic scaffolding analyzing the students’ behavior and knowledge in relation to the demands of the learning task (diagnosis). Based on their diagnosis, they select the right scaffold for the situation (calibrating). Finally, fading is a consequence of a continuous diagnosis and calibration cycle. As diagnosis and calibration continuously happen, the scaffolds are reduced when the students become more experienced (fading). Computer software has to perform the same processes to dynamically scaffold the learner. Yet, computer systems’ awareness and interpretation of students’ behavior in relation to the learning task is still restricted (Molenaar et al., 2011; Woolf, 2009). We used an attention management system to capture students’ attentional focus and used this information to implement dynamic scaffolding (Molenaar & Roda, 2008). Attention management systems can capture users’ attentional focus and determine costs associated with presenting certain information to learners (Molenaar & Roda, 2008). The utility of attentive systems for educational sciences is therefore related to the ability to detect students’ attentional focus and interpret this information. This enables the continuous assessment of students’ attentional focus, its interpretation (diagnosis) and by the selection of the appropriate scaffold (calibration) when needed (fading) (Molenaar et al., 2011).

**Scaffolding self-regulated learning**

Cognitive and metacognitive activities are key to self-regulating one’s learning in Computer-Based Learning Environments (CBLE’s) such as the Internet, electronic learning environments and games (Azevedo et al., 2010; Azevedo & Hadwin, 2005). Students who orientate, plan, monitor and evaluate learn more and show higher motivation than students who do not engage in these activities (Azevedo & Jacobson, 2008; Azevedo, Moos, Greene, Winters & Cromely, 2008; Bannert & Mengelkamp, 2008). However research has abundantly shown that students insufficiently regulate their learning in CBLE’s. Students struggle with the regulation of their learning; they do not formulate clear learning goals nor control their cognitive activities according to these goals (McCrudden & Schraw, 2007; Winne & Hadwin, 2010). Successful self-regulating learners use cognitive activities (read, process, elaborate) to study the learning domain, control and monitor their learning with metacognitive activities (orientate, plan, monitor and evaluate their actions) and motivate themselves (Azevedo et al., 2010; Zimmerman, 2002). Therefore, in order to support students’ self regulated learning, scaffolding should focus on supporting cognitive and metacognitive activities (Molenaar & Roda, 2008). Students’ perception of the learning environment interacts with their motivation to apply cognitive and metacognitive
activities (Zimmerman, 2002). Students’ perception about the software and their teacher can determine students’ investments and consequently influence their performance and learning (Howland & Moore, 2002; Martens, Bastiaans & Kirchner, 2007).

**Effects of scaffolding on learning**

As discussed above, scaffolding differs with respect to the types of scaffolds (static vs. dynamic). Moreover the modality (paper based, computerized or human tutors) and the focus of the scaffolds (cognitive and/or metacognitive activities) can vary. Below we discuss the results of different scaffolding studies on students’ learning. We emphasize the type, modality and focus of scaffolding.

First, we report on static scaffolding studies. Veenman, Kok & Blote (2005) analyzed the effects of a paper list of 6 metacognitive questions on the performance on math’s problems in a study of 12 year old children. Initially the students performed the learning task without the scaffolds and later with the scaffolds. Learning performance was measured by the number of correct answers and the grade for math. Students performed significantly better on problems supported with scaffolds compared to problems not supported with scaffolds. Bannert, Hildebrand & Mengelkamp (2009) assessed the effect of paper-based metacognitive scaffolds on learning outcomes of college students studying ‘psychological theories of using pictures in a multimedia environment’ in a hypermedia learning assignment. The learning outcomes were measured with a recall test, a domain knowledge test and a transfer task. The authors found no effects on the recall and knowledge test; they did found that the students in the experimental condition outperformed the students in the control condition with regard to the transfer task.

Bannert’s (2006) research evaluates static computerized scaffolds directed at cognitive and metacognitive activities. The author investigated the effect on the learning outcomes of college students studying “conditioning” in a hypermedia environment. Students were asked at every node change in a hypermedia environment to specify why they choose this node. The learning outcomes were assessed by a recall test, a domain knowledge test and a transfer task. Scaffolding only affected the outcomes on the transfer task; students in the scaffolding condition outperformed the students in the control condition. There were no differences between the two conditions with respect to recall and domain knowledge. Lin and Lehman (1999) looked at the effect of static computer scaffolds supporting problem solving on the near and far transfer performance on biology tasks. They found increased far transfer on contextually different problems when students were supported with the scaffolds. However, no effects of scaffolding were found on near transfer problems.

There are few studies with computerized dynamic scaffolding of self regulated learning. Metatutor is a computerized scaffolding system for self-regulated learning which has recently been developed to support students learning of the circulatory system (Azevedo et al., 2010). The first studies show that Metatutor successfully fosters student’s
self-regulated learning and facilitates learning of complex science topics (Azevedo et al., 2010). Azevedo and colleagues performed several studies (Azevedo et al., 2008) assessing students learning in a hyper media environment. The scaffolding was dynamic and delivered by a human tutor. They assessed learning outcomes by determining shifts in mental models and acquired domain knowledge (matching task, labeling task, flow diagram task). Students receiving scaffolds developed better mental models and acquired significantly more domain knowledge on the labeling task and the flow diagram task.

In summary, static scaffolding appears to increase problem solving and transfer of domain knowledge. However, no effects were found on the students’ domain knowledge. Dynamic scaffolding by a human tutor and computer-based systems, on the other hand, did affect domain and transfer of domain knowledge.

Our study

The aim of our study is to explore the effects of dynamic scaffolding with an attention management system on students’ learning and their perception of the learning environment. Research has shown effects of static scaffolding on problem solving and transfer of domain knowledge and dynamic scaffolding also improved student’s domain knowledge. However, to our knowledge no studies have been conducted so far into the effects of computerized dynamic scaffolds supporting students in middle school. The aim of our study is to evaluate these effects. Research indicates that students’ perception about the learning environment drives their motivation and consequently their investment in cognitive and metacognitive activities. Therefore we also assesses students’ perception and how this fluctuates during learning. The following research questions are addressed:

1. What are the effects of dynamic scaffolding of self-regulated learning on students’ learning?
2. What are the effects of dynamic scaffolding of self-regulated learning on students’ perceptions about the learning environment and does this fluctuate over the learning sequence?

In an experimental design a scaffolding condition is compared with a control condition. The students in the scaffolding condition are supported with cognitive and metacognitive scaffolds. These scaffolds are dynamically adjusted to the progress of the students. The control condition does not receive any scaffolds of their cognitive or metacognitive activities. Based on earlier scaffolding research the hypothesis is that the system will positively affect learning and perception of the students.

Method

110 students from 4 schools divided over 5 classes in the Czech Republic participated in this study. The students were in 5th grade and on average 11 years old, with ages ranging from 10.5 to 11.4. The teachers grouped students in 55 dyads within their classes based on
the principle of heterogeneity, balancing gender, school performance, and reading and computer abilities. The pairs in all classes were randomly assigned to one of two conditions. The control condition was formed by 27 dyads who received no scaffolds. The experimental group was formed by 28 dyads that were supported by scaffolds. The conditions were equally divided over the different classes. The dyads in the experimental group received scaffolds supporting their metacognitive and cognitive activities as will be described below in the section about the scaffolding system. The scaffolds were provided by a virtual agent (see figure 3). The dyads in the control condition did see the virtual agent but did not receive any form of support from the agent.

The total duration of the experiment was 6 lessons of 45 minutes each. During the lessons, pairs of students worked on an assignment called ‘Would you like to live abroad?’ The goal of the assignment was to learn about New Zealand, write a paper on the findings and decide if they would like to live in this country. The pairs worked on one computer with an electronic learning environment (Ontdeknet) through which students had access to an inhabitant of the country, their expert. Students could consult the expert by asking questions and by reading the information section about the country written by the expert. The final assignment, write a paper about New Zealand, was preceded by three preparation assignments: a self-introduction of the two students, the writing of a goal statement, and the design of a concept map specifying the topics of interest. All assignments were integrated in the working space of the pair where they also wrote their paper. In the first lesson the students were given instructions about the task. All students received the same instructions and spent the same time working on the assignment (4 hours). In the final lesson, students finished the assignment and the domain knowledge of individual students was measured.

Treatment: The scaffolding system

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 subject of expertise, knowledge about their country for this study. The experts’ contributions are edited by the (human) 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 in front of a computer.

For the purpose of the experiment, the Ontdeknet system was augmented with dynamic scaffolding. We refer to this new system as AtgentSchool (Molenaar & Roda, 2008). AtgentSchool includes an attention management system capable of determining when to send which scaffold to the learners. Attention management systems capture the attention focus of the students (Molenaar et al., 2011). 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.
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 students’ attention using the event information and the active task of the student. Based on this diagnosis of the students’ attention, a scaffold was selected that could be useful for the student. Finally, the intervention level determined how the scaffold should be communicated to the learner. AtgentSchool used a three-dimensional virtual agent powered by Living Actor© technology for the delivery of scaffolds (Morel & Ach, 2011). The scaffolds were shown in text balloons and could be heard as spoken messages through the computer’s audio output (see figure 3). 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 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).

Students’ pairs in the scaffolding condition received scaffolds supporting their cognitive and metacognitive learning activities during the first three lessons. The cognitive scaffolds were triggered when students indicated they needed help by clicking on the smiley in the screen or when the system monitored an idle user (prolonged absence of keyboard strokes or mouse movements). We implemented two types of cognitive scaffolds, cognitive support and cognitive resources. Cognitive support helped the learner with the current learning activity, whereas cognitive resource interventions provided students with links to resources in the learning environment that could help them perform the task. For example a cognitive support scaffold for the assignment ‘make a concept map’ would be: ‘What do you already know about the subject you are going to study?’; and a cognitive resource scaffold for the same task would be: ‘Need some ideas? You can read the introduction diary of the expert’.

The metacognitive scaffolds were delivered at times when metacognitive activities are generally executed in the learning process based on Zimmerman’s model(2002) for self-regulated learning. As mentioned above, the scaffolding system determined the appropriate instance to be sent on the basis of the students’ attention focus. Scaffolds were triggered by the system on the basis of the following changes in the attention focus of the students:

Orientation activities should be performed just before selecting a task; thus students who were recognized as moving their attention to a sub-task received a scaffold to orientate on the sub-task. For example an introduction scaffold for the task of setting a learning goal would be: “You can write a goal statement to explain to the expert why you choose his country and indicate what you hope to learn”. Planning should be performed just before starting a task; therefore planning scaffolds were implemented just before execution of the sub-task. For example a planning scaffold for a learning goal task would be: “A learning goal is what you want to learn. For instance, we would like to learn more about
New Zealand to decide if we would like to live there”. Finally, monitoring should be performed during and after execution of the task therefore, upon saving, the sub-task dyads were shown a scaffold prompting them to monitor (Molenaar & Roda, 2008). For examples a monitoring scaffold for the learning goal task would be: “I will send your learning goal to your expert to explain to him what you want to learn”.

For each sub-task and the main task three types of metacognitive scaffolds were implemented: orientation, planning and monitoring scaffolds. Students in the scaffolding conditions received a minimum of 12 metacognitive scaffolds.

![Figure 3. Example of the embodied agent in the learning environment providing a scaffold to the learner.](image)

**Measurements**

**Learning**

We measured student learning at two different levels: the dyads’ performance and individual student’s knowledge. The dyads’ performance was measured by evaluating their paper “Would you like to live in New Zealand?” The number of questions posed to the expert was also monitored as an indicator of the dyads’ performance. Papers were graded by two researchers who were asked to reach mutual agreement about the number of topics covered by the paper and the percentage text formulated by the students. The paper score was 1 if there were less than 4 topics covered or if the students scored low on self-formulated text. The score was 2 if students discussed between 4 and 8 topics and used a reasonable amount of self-formulated text. The maximum score of 3 points was received when students discussed more than 8 topics in mostly self-formulated texts.
Student’s domain knowledge was measured individually by a curriculum-based knowledge test with 15 true/false items related to New Zealand. Students received 1 point for each correct answer and 0 points for incorrect answers. Cronbach’s alpha, which is an indicator of the reliability of the test (Field, 2005), was 0.76 for knowledge test. The same test was used as pre-test and as post-test with 6 weeks in between the two measurements.

**Perception questionnaire**

The students’ perception about different aspects of the AgentSchool environment was measured with a questionnaire. The questionnaire was administered twice, once in the middle of the learning sequence (week 3) and once after the students were finished (week 7). The questionnaire was divided in 4 scales; the perception of the agent; the perception of the software; the perception of the teacher and of the collaboration with their peer. The perception of the agent dealt with questions about the 3D agent that provided the scaffolds to the students. This scale consisted of 6 items with a Cronbach’s alfa of 0.72. The perception of the software measured the students’ ideas about the software and consisted of 8 items with a Cronbach’s alfa of 0.67. The perception of the teacher included three questions about the role of the teacher during the experiment and had a Cronbach’s alfa of 0.63. The students’ perception of the collaboration was measured asking questions about the usefulness of collaborating with a peer on this task. This scale also consisted of three items with a Cronbach’s alfa of 0.83. The answer options were 1 through 5 with 5 indicating very good and 1 indicating very bad. See appendix 2A for an overview of the questions. The dyads filled in one questionnaire together, they were asked to come to an agreement about the answers.

**Analysis**

The data of the group performance measurements and application test data were not normally distributed, thus a Mann-Whitney test was used to analyze the effects on the dyads performance. The domain knowledge test was normally distributed thus a Mixed ANOVA with the scores on pre- and the post test was used as the within subject factor and the conditions (control, scaffolding) as between-subject factor.

The data of the perception questionnaire were normally distributed thus a Mixed ANOVA with the scores on 1st and the 2nd measurements of each scale was used as the within subject factor and the conditions (control, scaffolding) as between-subject factor. Four separate analyses were conducted one for each scale: the agent (Honza), the software, the teacher, and the collaboration. It is important to note that the first measurement was not a pre-test, but was taken in the middle of the learning assignment. The second measurement taken after the learning assignment was finished. 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$^4$.

**Results**

*Dyads’ performance and learning*

We assessed the effect of dynamic scaffolding on the learning performance of the dyads by comparing the control condition with the experimental group. The experimental group (Mdn= 2) significantly outperformed the control condition (Mdn=1) on the quality of their paper, $U = 268.5$, $p < .05$, $r = 0.26$. An effect size of $r = 0.26$, indicates a medium positive effect of scaffolding on group performance on the paper. Also, with respect to the number of questions asked there was a significant effect of scaffolding. The experimental group (Mdn= 1) significantly outperformed the control condition (Mdn=0), $U= 290.5$, $p < .05$, $r = 0.21$. An effect size of $r= 0.21$ shows a small to medium positive effect of scaffolding on the number of questions asked. These findings with respect to group performance confirm our prediction that attention based dynamic scaffolding did significantly affect group performance.

For the analysis of the development of domain knowledge we compared the pre- and post-test scores of students in different conditions. The main effect of time (post vs. pre-test) on domain knowledge was significant, $F(1,55)=137.5$, $p<.001$, $r= 0.85$, the main effect of condition (control vs. experimental) is not relevant in this case (not significant $p>.05$) and the interaction between time and condition was not significant, $p>.05$. Thus with regard to domain knowledge, the findings do not confirm our expectations: attention based dynamic scaffolding did not significantly affect domain knowledge. There was a large significant effect for all students between the pre- (m=6.61) and post -test (m=10.57), indicating that all students gained more domain knowledge.

*Perception questionnaire*

We will discuss the effects of time and conditions on the four scales of the perception questionnaire, namely the agent, the software, the teacher and the collaboration. The main effect of time on perception of the agent was significant, $F(1,38)=53.65$, $p<.001$, $r= 0.76$, the main effect of condition was not significant $p>.05$ and the interaction between time and condition was significant, $F(1,38)= 6.38$, $p<.05$, $r=0.38$. In the middle of the learning sequence all students were more positive about the agent compared to the end of the learning sequence. There was no significant difference in perception between students from the experimental group and the control group, but students in the experimental condition did shift their opinion more over time than the students in the control group (see

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$^4$ We use the effect size $r$ for both the parametric and non-parametric test following Rosenthal (1991) as described in (Field, 2005). The $r$ for non-parametric data is calculated on the basis of the data from the Mann-Whitney test, namely $r= \frac{z}{\sqrt{N}}$

For $r$ for the parametric data is calculated on the basis of the data from the repeated Anova $r= \frac{F^{1/2}}{F^{1/2}+dfr}$. 

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figure 4). Overall, all students reported a good perception of the agent, but over time this reduced to a neutral attitude.

![Perception of the agent graph](image)

**Figure 4. Perception agent at time 1 and time 2 of the control group and the experimental group**

![Perception of the software graph](image)

**Figure 5. Perception of the software at time 1 and time 2 of the control group and the experimental group**

The main effect of time on the scale software was significant, \( F(1,38)=7.75, \ p<.001, \ r=0.41 \), the main effect of condition was not significant \( p>.05 \) and the interaction between time and condition was significant, \( F(1,38)= 10.54, \ p<.01, \ r= 0.47 \). Students in both conditions were more positive about the software in the middle of the learning sequence than at the end, but again students in the experimental condition changed their perception about the software more drastically over time then students in the control condition (see figure 5). Students reported a positive to neutral perception of the software and students in the control group remained stable whereas students in the experimental condition dropped their perception to a neutral level.

With respect to the perception of the teacher the main effect of time was not significant, \( p>.05 \) the main effect of condition was significant \( F(1,38)= 12.87, \ p<.001\),
r=0.50, and the interaction between time and condition was not significant, p>.05. Thus students in the experimental condition are significantly more positive about their teacher, than the students in the control condition both in the middle as at the end of the learning sequence. Students in the experimental condition were positive about their teachers (m=4.05), whereas students in the control group were more neutral (m=3.30). Finally, the main effect of time on the perception of their collaboration was not significant, p>.05 the main effect of condition was significant, F(1,38)=4.60, p<.05, r=0.33, and the interaction between time and condition was not significant p<.05. The students in the experimental condition (m=4.05) are more positive about their collaboration than students in the control condition (m=3.56) both in the middle as at the end of the learning sequence.

Conclusion and discussion

This study contributes to the existing body of knowledge on scaffolding self-regulated learning by showing the effect of dynamic scaffolding supported by an attention management system on several aspects of the learning processes. Dyads in the scaffolding condition received context specific scaffolds to support their cognitive and metacognitive activities. Dynamic scaffolding, as implemented by AtgentSchool, had a positive effect on dyads’ performance leading to a higher quality of their paper and more questions asked. However, students receiving scaffolds did not gain more domain knowledge. Thus even though students wrote better papers and asked more questions, this did not lead to more domain knowledge. However, the better quality of the papers could be explained by better structuring of their knowledge, a better understanding of the task and what is relevant to compare two countries. The focus of the assignment was on writing the paper comparing the Czech republic with New Zealand and acquiring new information by asking questions. All students had gained significantly more domain knowledge after the learning sequence, indicating that they all learned.

Next we discussed the results of students’ perception during and after the learning assignment. Students in the experimental group reported more positive perceptions of their teacher and were more positive about the collaboration both during and at the end of the learning sequence. However, with respect the perception of the software and of the agent, the scores of students in the control and experimental group did not differ significantly. Yet the students in the experimental group did shift their perception more over time. This requires an explanation as we expected the experimental group to have a more positive perception of the software and the agent compared to the control group. The students give more positive evaluations of the environment at the beginning, probably because they are surprised by its reactivity. However as time passes students become used to it, they probably don’t “see” the system anymore but they concentrate on the learning task. Another explanation for the larger shifts in perception of students in the experimental condition might be that during the first lessons students received many metacognitive scaffolds. These scaffolds were faded during the latter lessons. The metacognitive scaffolds were automatically provided by the system based on the cyclical model of
Zimmerman (2002). Cognitive scaffolds could also be sent later in the learning sequence, but must be initiated by help-questions of learners. Thus for the selection of these scaffolds the system was largely dependent on students’ own ability to indicate that they need help. The fact that students received less scaffolds with time could also explain students’ shift in perception.

The students receiving scaffolds had a more positive perception of their teachers. As students were divided equally over the conditions within a class, this effect is not dependent on specific teachers. Also students in the experimental group felt better about their collaboration. We can image two possible explanations. First, students value their teachers and peers more after working with the agent because, compared to the agent, teachers and peers are better collaborative partners. Second, students that received scaffolds were able to formulate better questions for their teachers and peers and therefore had a more satisfactory interaction. In this case the interaction among the students was enhanced by the scaffolding.

Overall, the findings indicate that dynamic scaffolding of self-regulated learning can be given form with an attention management system. Dynamic scaffolding increases dyads’ performance on the learning task. However, the perception questionnaires indicate that the system is perceived more useful at the beginning than at the end as shown by the larger shift in perception of the software and the agent of the experimental group compared to the control group. Naturally, these findings need to be validated in different settings with different students and assignments, but these first results do indicate that dynamic computerized scaffolding with attention management could be a promising method towards dynamic computerized scaffolding.

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Appendix 2A.

Table 2A. Perception questionnaire items

<table>
<thead>
<tr>
<th>Question</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Honza helped us a lot</td>
<td>Perception of the agent</td>
</tr>
<tr>
<td>2. Software does what we want it to do</td>
<td>Perception of the software</td>
</tr>
<tr>
<td>3. Software does nothing we want it to do</td>
<td>Perception of the software</td>
</tr>
<tr>
<td>4. Honza looks great</td>
<td>Perception of the agent</td>
</tr>
<tr>
<td>5. Honza is really friendly</td>
<td>Perception of the agent</td>
</tr>
<tr>
<td>6. Honza is very helpful</td>
<td>Perception of the agent</td>
</tr>
<tr>
<td>7. Honza is very annoying</td>
<td>Perception of the agent</td>
</tr>
<tr>
<td>8. I think Honza likes us a lot</td>
<td>Perception of the agent</td>
</tr>
<tr>
<td>9. The software reacts immediately on our actions</td>
<td>Perception of the software</td>
</tr>
<tr>
<td>10. We understand what software tells us</td>
<td>Perception of the software</td>
</tr>
<tr>
<td>11. We like the look of the software</td>
<td>Perception of the software</td>
</tr>
<tr>
<td>12. We know what we are doing with the software</td>
<td>Perception of the software</td>
</tr>
<tr>
<td>13. We feel in control of the software</td>
<td>Perception of the software</td>
</tr>
<tr>
<td>14. Screen instructions were helpful</td>
<td>Perception of the software</td>
</tr>
<tr>
<td>15. We understood our teacher’s instructions</td>
<td>Perception of the teacher</td>
</tr>
<tr>
<td>16. It is good to ask our teacher a question</td>
<td>Perception of the teacher</td>
</tr>
<tr>
<td>17. Our teacher knew all about the software</td>
<td>Perception of the teacher</td>
</tr>
<tr>
<td>18. We really enjoyed the lessons</td>
<td>Motivation</td>
</tr>
<tr>
<td>19. We divided the work equally</td>
<td>Perception of the collaboration</td>
</tr>
<tr>
<td>20. We shared typing equally</td>
<td>Perception of the collaboration</td>
</tr>
<tr>
<td>21. We shared deciding equally</td>
<td>Perception of the collaboration</td>
</tr>
</tbody>
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