It’s all about metacognitive activities: computerized scaffolding of self-regulated learning
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Abstract  This chapter addresses how an attention management system can support dynamic scaffolding for self-regulated learning. An attention management system captures information from the students’ environment about the students’ attentional focus. In this chapter we propose a conceptual framework to interpret this information to provide dynamic scaffolds to the learner. The essential elements to select appropriate scaffolds are diagnosing, calibrating and fading. Our intervention model defines how to support self-regulated learning with different scaffolds. The three component processes of self-regulated learning are supported, namely cognition, metacognition and motivation. This chapter is concluded with a short description of the testing procedure that assured the proper functioning of the software.

Introduction

E-learning has incrementally changed education in recent decades. Many new tools and instruments have been introduced to support existing educational practices. Yet only on a small scale have we seen transformative processes in schools (Mioduser, Nachmias, Tubin, & Forkosh-Baruch, 2003; Woolf, 2009). The large changes which have taken place in other sectors have not yet been achieved in education. This can partially be explained by the fact that e-learning solutions are not yet flexible enough to cater to learner’s individual needs and demands. We see personalization in many sectors today, but education still seems to hold on to the ‘one size fits all’ paradigm even though we know that personalized education is more effective than standardized education (Bloom, 1984).

Artificial intelligence has provided personalized solutions, but these programs are mainly applicable in structured domains (Woolf, 2009). Often artificial intelligence programs construct a model of the student’s knowledge based on the student’s answers to questions. The comparison of the student’s knowledge model to a domain knowledge model supports the selection of new assignments and/or support messages for the student. In ill-structured domains, it is difficult to build knowledge models of the student’s knowledge because answers are difficult to interpret (Lynch, Ashley, Pinkwart & Aleven, 2009). Therefore, few personalized solutions are available in ill-structured domains.

Attention management addresses the quest for personalization on a different level. Instead of building models of the domain knowledge and comparing this to the student’s knowledge model, it focuses on capturing the user’s attentional focus (Roda & Nabeth, 2007). This attentional focus can be built upon to provide personalized instruction and allowing for dynamic support of learning. Attention management systems integrated with electronic learning environments can provide learners with the help they need to direct and sustain attention to appropriate tools and information. This support can evolve with the student’s knowledge and skills and is often referred to in the literature as scaffolding (Wood, Bruner & Ross, 1976). Although scholars stress the importance of scaffolding self-regulated learning, especially in open electronic learning environments (Azevedo & Hadwin, 2005), research into the role and effectiveness of computerized scaffolding in supporting self-regulated learning is scarce.

This chapter addresses a design-related question: how can an attention management system enable personalized support, or dynamic scaffolding, of self-regulated learning? In order to answer this question, we describe the theoretical construct of scaffolding and its related dimensions. We will explain how attention management is related to the scaffolding theory and elaborate on the relation between self-regulated learning and scaffolding.
Scaffolding

Scaffolding provides assistance to a student on an as-needed basis, fading the assistance as the student’s competence increases (e.g., Wood et al., 1976). The scaffolder can be either a human tutor or a tool embedded in the computer environment. Three important elements in scaffolding are diagnosis, calibration and fading (Puntambekar & Hübscher, 2005). The abilities of the learner must be diagnosed continuously in order to define appropriate scaffolding. This diagnosis supports careful selection, or calibration, of the right scaffolds to support the student and a reduction of support, fading, when the learner masters all aspects of the task.

Within the scaffolding paradigm, there is a distinction between static and dynamic scaffolding (Puntambekar & Hübscher, 2005; Molenaar & Roda, 2008). Static scaffolding is defined at one moment, constant over time and the same for all students; for instance, one may provide a list of instructions to help users perform a learning activity. Dynamic scaffolding entails pedagogical agents which diagnose, calibrate and fade their support in an individualized manner such that one can monitor the student’s progress and provide scaffolds when needed during learning. Static scaffolding can support learners to increase performance. Dynamic scaffolding has the additional benefit that it can help students learn when to apply certain knowledge or skills during learning. The term scaffolding is often used in cases where static scaffolding is applied: the amount and type of support is fixed and not adjusted based on a diagnosis of the student’s learning (Puntambeker and Hübscher, 2005). There is no calibration of the scaffolds to the changing needs of the individual student nor fading of the scaffolding; the scaffolds are permanent and unchanged. We propose using attention management to support dynamic scaffolding, applying diagnosis, calibration and fading based on the students’ attentional focus and information from their environment.

Next to the distinction between static and dynamic scaffolding, another important issue for the design of scaffolds is the focus of the support. As mentioned above, scaffolding plays a crucial role for learning in largely unguided and open learning environments (Kalyuga, Chandler & Sweller, 2001; Kirschner, Sweller & Clark, 2006). In these learning environments scaffolding should be directed at self-regulated learning and support students to successfully learn in these environments (Azevedo & Hadwin, 2005). Self-regulated learning is defined as self-generated thoughts, feelings and behaviors directed at attaining learning goals; it deals with the component processes: cognition, metacognition and regulation of motivation (Ainley & Patrick, 2005). Cognitive activities are directed at the acquisition of knowledge while metacognitive activities are directed at monitoring and controlling these processes. Motivation strongly influences learning activities (Boekaerts, 1999) and regulation of motivation plays an important role in the attainment of learning goals (Ainley & Patrick, 2005; Boekaerts, 1999; Mayor, 1998, Zimmerman, 2002). In order to scaffold all three component processes we developed an intervention model from which scaffolds for each one of the processes are selected. Before
we turn to an explanation of the scaffolding system, we will briefly introduce the reader to some fundamental concepts in human attention that has guided our research.

**Attention**

Attention can be defined as the collection of processes regulating the allocation of a human’s limited cognitive resources. Attention allows us to select some perceptual input for further processing out of the wide variety of stimuli we continuously receive from the environment. Attention also controls the allocation of cognitive resources to the processing of multiple tasks, enabling task monitoring and error detection. Finally attention allows us to create expectations that guide the selection of perceptual stimuli, as when we recognize a person we were waiting for in a crowd. Attention, or the allocation of cognitive resources, may be controlled either endogenously by volition or exogenously when temporarily directed by external stimuli (Posner, 1980; Yantis, 1998). For example, when reading this document, you are applying endogenous attention because you choose to pay attention to the document; however, a sudden noise may exogenously control your attention and temporarily redirect it to the source of the noise.

In general, attention allocation can be observed at several levels of granularity; that is, we may say that a subject is paying attention to a vertical bar on a screen, to a letter ‘t’, to a word ‘table’, to a sentence ‘the glass is on the table’, to a document describing a room layout, to the task of verifying if the description of a room layout corresponds to the room the subject is in, etc. The literature often distinguishes between two granularity levels, the perceptual level and the task level. We can distinguish several different forms of attention. Focused attention is directed to an individual task or input channel. If the focus is prolonged, then we have sustained attention. Because by focusing on a certain target one excludes others, focused attention implies selective attention (Chun & Wolfe, 2001; Driver, 2001; Posner, 1982). An attention switch is the process by which attention is moved from one target to another. There is always a cost involved in attention switches (Jersild, 1927; Monsell, 2003) due both to the uncertainty associated to the task to be performed in response to a stimulus (Spector & Biederman, 1976) and to the cost of reconfiguring the current task set (Monsell, 2003). Often, rather than switching attention, we are able to allocate attention to multiple tasks or channels at the same time. In this case we talk about divided attention; for example, we can easily drink a cup of coffee while reading a book.

The fact that attention plays a fundamental role in learning has been demonstrated in the context of several types of learning processes. Single-task versus dual-task experiments, for example, have demonstrated that implicit learning, the ‘no episodic learning of complex information in an incidental manner, without awareness of what has been learned’ (Seger, 1994 p. 163), requires attention, and it is penalized under dual-task conditions (Shanks et al., 2005). Similar results (Toro et al., 2005) have been obtained for statistical learning (Saffran et al., 1996). Several experiments (e.g. Ahissar & Hochstein, 1993) have also demonstrated the need for focused attention in learning task-relevant
information in perceptual learning, that is, the improvement of perceptual abilities after training. Task-related focused attention in perceptual learning generates an alerting process that may also explain the unexpected effect of task-irrelevant learning (Seitz & Watanabe, 2005). Finally, attention also affects higher-level learning, e.g. the learning of written language or mathematics (Lok, Jin & Sweller, 2011).

Given the role that attention plays in learning processes, attention management systems i.e. systems capable of adapting to and supporting human attention processes (Roda & Thomas, 2006), promise to play an essential role in supporting technology-enhanced learning environments. 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, such as the one introduced in the next sections, is to detect the attentional focus of the student and interpret this information to support learning.

Scaffolding with an attention management system

For a detailed technical description of the AtgentSchool system we refer the reader to Molenaar & Roda (2008). In this chapter we will describe the system’s functioning from an educational perspective, which oversimplifies its technical functioning. First, we will explain how the system is related to the scaffolding theory incorporating diagnosis, calibration and fading. Secondly, we elaborate on the relation between the self-regulated learning and the interventions the system uses to scaffold learning.

AtgentSchool

The AtgentSchool system is an e-learning environment combined with an attention management system. The e-learning environment incorporated with AtgentSchool is called Ontdeknet, and is focused on supporting students in their collaboration with experts (Molenaar, 2003). Ontdeknet is an open learning environment in which assignments are structured in ‘projects’. A project consists of a broad overall assignment which is connected to an external expert who will provide the students with specialized information. The assignment is divided into smaller sub-assignments to support the collaboration with the expert; students are asked to introduce themselves to the expert, write a goal statement and specify topics of interest on a concept map.

AtgentSchool’s attention management system monitors the students’ attentional focus and based on that information supplies them with support to enhance their learning. The system’s technical design consists of three levels, the input level, the reasoning level and the intervention level. The input level collects the attentional information from the students’ environment. Currently, input is based on keyboard strokes, mouse movements and information about the students’ activities in the e-learning environment which is captured by the log file. The reasoning level selects a scaffold that is sent to the learner.
Different software agents assess the attention information to select the appropriate scaffold. The intervention level determines how the scaffold is communicated to the learner. AtgentSchool uses a three-dimensional animated pedagogical agent powered by Living Actor technology (Benoit & Ach, 2011) for the delivery of scaffolds via text balloons and spoken messages accompanied by the agent’s animations and emotions. The student has four icons in the interface to communicate with the agent, a question mark to indicate a need for help and three emotional icons indicating a happy, neutral or sad user. This information from the user is used as additional input. In the section below, we explain how diagnosis, calibration and fading are performed with the AtgentSchool system.

**Diagnosis**

Diagnosis is defined as the ongoing measurement of the students’ current level of understanding to select the appropriate scaffolding (Wood et al., 1976). This entails the evaluation of the users’ progress during learning activities. Progress is evaluated based on the students’ performance on the learning assignment and/or the students’ development of knowledge in the learning domain (Wood et al., 1976). Diagnosis in AtgentSchool is based on the attention information acquired in the students’ environment. The system registers the students’ progress based on his performance in the learning environment. For example, when the learner browses through a text, the system registers both the viewing of the particular text as well as the browsing behavior of the student. The information from the electronic learning environment is particularly important because it provides a real-time description of activity on the learning assignment. Based on this information, the learners’ progress and experience is registered. For example, if a learner is using the concept map tool in the learning environment and proceeding quickly, filling-in different fields, this information is stored with an indication that the learner is capable of appropriately using the concept map tool. Both the current behavior of the student as well as the experience and progress are incorporated in the diagnosis.

Additionally, keyboard strokes and mouse movements provide information beyond the level of involvement in the specific learning task by also measuring the students’ activities in the overall environment. For example, no keyboard strokes or mouse movement registration in a certain time frame can indicate that the student is idle. The students’ current attentional focus is evaluated on the basis on this input-level information (data related to the performance, progress, experience, keyboard strokes and mouse movement) and it constitutes the diagnostic component of AtgentSchool.

**Calibration**

Following diagnosis, calibration is the careful selection of the best scaffold for the student’s activity (Wood et al., 1976). The system assembles a logical attentional focus based on the learning assignment at hand and creates a list of all possible scaffolds that can support the learner at this instant. The learner’s current attentional focus is compared to the logical attentional focus based on the learning assignment. When current and logical
attentional focus match, a scaffold is selected to support the learner with his current activities. For example, if a student should introduce himself and is at the screen prompting him to enter the introduction then, if the system detects that the student is idle, it may support the student by suggesting that he starts planning the introduction assignment. In case of a discrepancy between the current and the logical attentional focus, the system is triggered to select a scaffold that can overcome the discrepancy. For example, if the student has an assignment to introduce himself and the system establishes that he is not on the correct screen, then a focus discrepancy is diagnosed and a scaffold is selected to direct the attention of the learner to the introduction assignment, yet the system will wait to provide the scaffold until it registers that the student is idle. Calibration has the function of determining the most appropriate scaffold based on the diagnostic information. Scaffolds either support or alter the attentional focus of the student.

Fading

The final element of scaffolding is fading. Fading is the gradual reduction of scaffolds leading to full transfer of tasks and control to the learner (Wood et al., 1976). The nature and amount of fading is highly dependent on the experience of the user: when the student masters all aspects of the tasks, no scaffolds are needed to support self-regulated learning. In AtgentSchool the learners’ progress and experience is registered. This information is used to determine whether the scaffold selected in the calibration process should be forwarded to the student. If the system determines that scaffolding is not needed for a student, fading ensures that the scaffold is not sent. For example, when the system registers the students’ focus on the introduction assignment, it will send a scaffold only if the student has not worked at the introduction previously. Thus fading, in the AtgentSchool system, is achieved by selecting appropriate scaffolds based on an assessment of the learners’ progress and previous experiences. If the diagnostics of the system and the registered user information contradict each other, fading will be reduced. For example, if the learner model indicates that the user is an experienced user and the diagnostics of the system show that the user does not perform the task correctly; the system will reduce the fading and show the supporting scaffold to the user.

To summarize, the attention management system derives information from the students’ environment. Based on this information an assessment of the attentional focus of the student is made (diagnosis), which is compared to a logical attentional focus based on the learning assignment. This comparison is the basis for the selection of the scaffold (calibration), which is only sent when the student needs support (fading). Now that we have defined how scaffolds are selected in relation to the attentional focus of the students, we identify which learning activities the scaffolds are supporting.
Chapter 1

**The intervention model**

An important aspect for dynamic scaffolding to become effective is the focus of the scaffolds. The scaffolds are directed toward three different but related components of self-regulated learning, cognition, metacognition and motivation. In order to design scaffolds that are focused on these processes, the AtgentSchool system uses a standardized intervention model (Molenaar & Roda, 2008) from which the scaffolds are selected. There is an important difference between interventions and scaffolds. Interventions are the messages that can be shown to the learner to support learning, but they only become scaffolds when they are presented in the right learning context. The intervention model consists of three intervention categories, metacognitive interventions, cognitive interventions and motivational interventions. The intervention categories are further organized by intervention types (see Table 1 for an overview). The intervention types are general and transformed in task-related scaffolds depending on the students’ context. The different intervention categories are described below; the function of each intervention is discussed followed by an explanation of how the intervention is used during learning and relates to the attentional focus of the student.

**Metacognitive interventions**

Metacognition is defined as the knowledge about and regulation of one’s cognitive activities (Flavell, 1979). Metacognitive activities are categorized as preparatory activities such as orientation and planning, executive activities such as monitoring and evaluation and closing activities such as reflection (Zimmerman, 2002; Veenman, Aftenbach, van Hout-Wolters, 2006). Orientation on a learning assignment supports a detailed view of the task at hand and the activation of prior knowledge relevant to the task. Planning a learning assignment entails dividing it into subtasks and deciding on the strategies to be followed to complete the sub-tasks. Through monitoring, students check the correctness of their learning. Evaluation enables students to react to failures and misunderstandings. Reflection about the learning procedures and strategies provides grounds for future enhancement.

Metacognitive interventions are directed at supporting and triggering metacognitive activities. These interventions can support learning when they are shown to the learner at times when metacognitive activities are beneficial for learning. AtgentSchool supports three forms of metacognitive scaffolds, orientation, planning and monitoring scaffolds. **Orientation** is best performed just before task selection; thus when the attentional focus of the students is about to change towards a new assignment, students are shown a scaffold with which to focus on the assignment. An example of an orientation scaffold for the ‘goal statement’ assignment is: ‘Your expert would like to know what your learning goal is; could you tell him? Please click here to write your learning goal.’ **Planning** is done just before starting a learning assignment; therefore, planning interventions are implemented just after the attentional focus of the student shifts from one assignment to another. The following sentence is an example of a planning scaffold for the ‘goal statement’ assignment (see figure 2): ‘Here you will write your learning goal; for example, I like to
learn everything about David. Just kidding, good luck.’ Finally, monitoring should be performed during and after execution of the assignment, just before the attentional focus of the student moves away from the assignment. The following sentence is an example of a monitoring scaffold for the ‘goal statement’ assignment: ‘I’ll go directly to your expert and explain what you would like to learn.’

Figure 2. Example of metacognitive planning intervention

Cognitive interventions

Cognitive activities are directed toward the acquisition of knowledge (Nelson, 1996). Cognitive interventions can provide the knowledge and skills necessary to perform an assignment and are best shown to learners when there is an indication that they are experiencing problems. Indications of problems could be an idle user, when there are no keyboard strokes or mouse movements, or when the user indicates he needs help via a question mark icon in the interface. The selection of the cognitive interventions is determined by the attentional focus of the learner. Two different types of cognitive interventions are distinguished, cognitive support interventions and cognitive resource interventions. Cognitive support interventions are directed toward helping the learner with the current learning activity whereas cognitive resource interventions provide students with links to resources in the learning environment that can help them perform the task. For example, a message to the user saying ‘What do you already know about the subject you are going to study?’ is a cognitive support scaffold for the assignment ‘write a concept map’: an example of a cognitive resource scaffold for the same learning task would be: ‘Need some ideas? You can read the introduction diary of the expert’.

Motivational interventions

Motivation strongly influences students’ learning activities (Boekaerts, 1999), and motivational support can increase learners’ motivation. Motivational interventions are directed at increasing learners’ motivation to work on the learning assignment. They are best shown when there is an indication that the user is having problems to keep up his motivation. An indication of motivational problems occurs when users indicate their motivation to the agent. Also motivational interventions are triggered when the user is idle and there are no new cognitive interventions available for this user. The selection of the
motivational support intervention is determined based on the attentional focus of the learner. General motivational interventions are implemented in the system. An example is: ‘You can do it! Just start writing’. Additionally, when the user indicates his current emotional state with happy, neutral or sad smiley’s, the agent mirrors the state of the user by showing an animation and expression that resemble the user’s state. The three forms of emotional feedback lead to three emotional support interventions where the embodied agent responds to a user’s notification of a happy, neutral or sad emotional state. The intervention categories and intervention types are summarized in table 1.

Table 1. A summary of the intervention categories and types

<table>
<thead>
<tr>
<th>Intervention Category</th>
<th>Intervention Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metacognitive</td>
<td>MC orientation</td>
<td>Introduces the learning assignment to the learner</td>
</tr>
<tr>
<td>Metacognitive</td>
<td>MC planning</td>
<td>Asks the learner to plan the learning assignment</td>
</tr>
<tr>
<td>Metacognitive</td>
<td>MC monitoring</td>
<td>Provides feedback to the learner about the learning activity performed</td>
</tr>
<tr>
<td>Cognitive</td>
<td>Cognitive support</td>
<td>Provides additional explanation to the learner</td>
</tr>
<tr>
<td>Cognitive</td>
<td>Cognitive resources</td>
<td>Provides additional explanation by redirecting the learner to another learning resource containing additional information</td>
</tr>
<tr>
<td>Motivation</td>
<td>Motivation support</td>
<td>Provides a motivational incentive to the learner</td>
</tr>
<tr>
<td>Motivation</td>
<td>ES Happy</td>
<td>Reacts to a happy learner</td>
</tr>
<tr>
<td>Motivation</td>
<td>ES sad</td>
<td>Reacts to a sad learner</td>
</tr>
<tr>
<td>Motivation</td>
<td>ES neutral</td>
<td>Reacts to a neutral learner</td>
</tr>
</tbody>
</table>

Relationships are established between the attentional focus of the learner, the learning assignment and the scaffolds selected. Both the cognitive and motivational scaffolds are selected based on the assignment that is currently in the attentional focus of the learner. They can also be triggered by the ‘user reaction’ icons, the question mark and emotional icons. Metacognitive scaffolds, on the other hand, do not have a direct relation with the assignment currently in the attentional focus of the students. Metacognitive interventions provide pre-task, on-task or post-task support; they are presented to the learner when he/she changes focus. Thus when the learner is about to select a sub-assignment, the metacognitive orientation intervention could be shown. At the start of the assignment an metacognitive planning intervention could be shown, whilst metacognitive monitoring interventions may appear while working on a task. Thus the positioning of metacognitive scaffolds is connected to the registered changes in the learners’ attentional focus. This allows for dynamic support of the students’ metacognitive activities.

It is more difficult to effectively position cognitive interventions in relation to the information about attentional focus the system currently retrieves. Input to the AgentSchool system currently only provides information allowing limited inferences about the cognitive activities of the student. The system knows which activity the student is working on but has no information about the students’ knowledge-building process. This
means that AtgentSchool can position the adequate cognitive support in relation to the current task and the progress of the student, but it is unable to align the cognitive interventions with the students’ knowledge acquisition. The question mark icon in the interface is currently the most important indicator that the students need additional support. Thus AtgentSchool can provide cognitive interventions to support the cognitive activities, but cannot adjust the support given to the students’ knowledge. Also the trigger of cognitive support is dependent on the students’ ability to monitor their own cognitive activities. This means that the positioning of cognitive interventions based on the current registration of attentional focus in AtgentSchool is limited.

Motivational interventions are similarly difficult to position in relation to current information about the students’ attentional focus. The input in AtgentSchool provides no information about the students’ motivational state other than the information students provide voluntarily via the icons in the interface. Based on this input we can support students on the motivational level, but the trigger of this support is largely dependent on the students’ ability to monitor their own motivational states. For the motivational interventions as well, we can conclude that the current registration of the attentional focus in AtgentSchool only supports motivational scaffolding to a limited degree.

So far, we have addressed the question: how can an attention management enable personalized support, or dynamic scaffolding, of self-regulated learning? We have discussed how the AtgentSchool system uses the information from the students’ environment to interpret the students’ attentional focus. Based on this attentional focus, scaffolds that can support self-regulated learning are selected using the diagnosis, calibration and fading. Thus in AtgentSchool, the attention management system allows for dynamic scaffolding to support the learners. We predict that the AtgentSchool system in its current form is particularly capable of scaffolding the metacognitive activities of the students, whereas it will only be effective at scaffolding cognitive activities and motivation when students are capable of indicating their need for help themselves.

**In practice: test-runs**

The sections above explained how our attention aware system is enabling dynamic scaffolding. In order to test the stability and functioning of AtgentSchool before the study in the Czech Republic, pre-tests were done in six schools in the Netherlands. The main purpose of these tests was to ensure the proper functioning of the system with real users and a representative user load, as well as collecting preliminary results on how learners perceived working with the system. The test runs were one hour sessions in which students were asked to work on the project ‘Where do you want to live?’ in which they researched another country based on information provided by an expert who lives in that country. Students worked on the project for 45 minutes performing the following learning activities: 1. introducing themselves to the expert, 2. setting a learning goal, 3. filling in a concept map, 4. reading a diary of the expert and 5. asking a question. This was a shorter version of the project later used in the studies. Six test runs were performed with 108 students aged...
between 9 and 12. Students received a 5 to 10 minute introduction to the task as testers of AtgentSchool and to the project ‘where do you want to live?’. During the sessions they were asked to use the smileys in the screen (happy, neutral, sad) to indicate how they felt about the agent. After their session they filled out a questionnaire about their perception of the agent and a short interview was conducted to further assess their perception of different scaffolds. In three test runs students were also shown interventions on a digital school board and they were asked to rate the interventions and to write down any comment they had.

**Results**

We analyzed the logs of the sessions to confirm that all scaffolds were selected according to the conceptual framework. A few interventions were studied in more detail and some debugging was done in relation to these findings. The children were asked to indicate how they felt about the scaffolds with the smiley buttons. Unfortunately, these were used very infrequent, because students were not able to attend a new task, read the scaffolds, act accordingly, and also indicate how they felt with the smiles. Based on these findings, the feedback acquisition was redefined and we developed a session with children judging the scaffolds on the smart board in a classroom session after the test run session. The students were asked to rate the scaffolds on a five point Likert scale and to write down their comments. The cognitive and metacognitive scaffolds were judged to be very good; the motivation scaffolds were judged neutral (see table 2).

<table>
<thead>
<tr>
<th>Scaffolds</th>
<th>Cumulated average judgment of student</th>
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<tbody>
<tr>
<td>Metacognitive scaffolds</td>
<td>4.03 = good</td>
</tr>
<tr>
<td>Cognitive scaffolds</td>
<td>3.71 = good</td>
</tr>
<tr>
<td>Motivational scaffolds</td>
<td>2.70 = not good not bad</td>
</tr>
</tbody>
</table>

The analysis of the questionnaires produced very encouraging results. 90.5% of the children wanted to work with the agent David again; 62% wanted to work with an agent more often; 9.5% would have liked to work with a different agent than David. The agent provided good help according to 90% of the children, and the two students that disliked the agent found that more help could have been provided. Students gave David a 7.5 average grade (girls a 8 and boys a 7)

Based on these test runs we ensured the proper functioning of the software for the first study. We improved the motivation interventions trying to address the users’ feedback. We adjusted aspects of the original configuration of the motivational support, instead of trying to respond the users’ motivational input the agent now just mirrors their motivational state. The configuration of the metacognitive and cognitive support was
judged positively by the users and therefore maintained. The agent David, (see figure 2) which had been developed within the Atgentive project, was well liked by the Dutch students.

Discussion

We began this chapter proposing that attention management could be used to personalize education. We have discussed how AtgentSchool enables dynamic scaffolding during learning with an attention management system. The attention management system derives information from the students’ environment. Based on this information, an assessment or diagnosis of the students’ attentional focus is made and then compared to a logical attentional focus based on the learning assignment. This comparison is the basis for the selection of the scaffold, or calibration, which are only sent when the student needs the support. AtgentSchool uses an intervention model directed at supporting self-regulated learning with metacognitive, cognitive and motivational scaffolds. The different scaffolds are shown to the user based on diagnosis, calibration and fading decisions made by the attention management system.

We expect that the current input into our system is rather limited to support the diagnosis of the students’ cognitive and motivational development. However the test- runs indicated that the students were positive about the cognitive scaffolds. Registering more and different information from the students’ environment would allow us to accumulate a better representation of the learners’ attentional focus. This could enhance our ability to position interventions in relation to the students’ cognitive activities and motivation. For example, the effectiveness of cognitive scaffolds could be enhanced using eye tracking, which would allow a better diagnosis of learners’ current cognitive activities and the use of a webcam to assess the students’ emotional state could help to provide more input for the diagnosis of learners’ motivation.

During calibration the students’ attentional focus is used to select a scaffold; for example, selecting a planning scaffold at the moment the learner starts a new task. Again the system could be enhanced with respect to cognitive scaffolding; for instance, if we know more about the learners’ knowledge, we can adjust the cognitive scaffolds to provide more adjusted scaffolds. Finally, adjustments could be made in the presentation of scaffolds to the user. The form and modality of the scaffolds can be modified. In our studies we have used the virtual agent, but one can think of many other possible modalities that give interventions such as text, agents or robots. The effects of these modalities on learning are largely unknown. Additionally, with respect to the virtual agent, we know very little with respect to the usage of his emotions, appearance, animations and their effects on learning outcomes.

In sum, we specified how an attention management could be used to support learning on a personalized level. Artificial intelligence has traditionally struggled with ill-structured domains resulting in few personalized solutions for these fields. Attention management
systems are domain-independent and thus can also be used in ill-structured domains. This means that learning systems augmented with an attention management system could be an interesting path of exploration that would enhance the availability of personalized learning solutions.

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