Animated Pedagogical Agents: An Opportunity to be Grasped?

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In open learning environments students are confronted with complex tasks. Learners have control over the environment and decide themselves over the use of support tools. However, research indicates that merely providing students with these tools does not result in their actual use. In this article possibilities of animated pedagogical agents to enhance the use of support tools are explored. First, a typology is constructed to describe and compare the different pedagogical agents from an instructional design perspective. Second, currently available pedagogical agents are analyzed, and finally empirical research on pedagogical agents in educational settings is reviewed. The conclusion discusses future research perspectives.

The use of open learning environments is advocated when learning complex problem-solving skills (Jonassen, 1997). These environments are characterized by at least three features. First, students receive a complex task that has to be examined from different perspectives to generate a suitable solution (Spiro, Feltovich, Jacobson, & Coulson, 1991). Second, support tools are embedded in the environment. Their use may help to solve the problem by structuring the problem-solving process or by providing problem-solving tools. And third, learners are responsible for their own learning and decide themselves on the use of these supportive elements. In other
words, there is a large amount of learner control (Hannafin, 1995).

In spite of strong theoretical arguments in favor of open learning environments, research demonstrates that students in open learning environments do not optimally use accessible support tools (Clarebout, Elen, Lowyck, Vandendriessche, & Lagana, 2000; Crooks, Klein, Jones, & Dwyer, 1996; Land, 2000). Students seem not always capable to make the appropriate choices (Clark, 1991; Large, 1996; Hill & Hannafin, 2001; Lee & Lehman, 1993; Shaw, Johnson, & Ganesha, 1999). This has a negative impact on the effectiveness and efficiency of learning in open learning environments.

How to encourage learners to make more ample and deliberate use of support in open learning environments is therefore an important question from an instructional design perspective. Two developments seem especially relevant in this respect. The first one relates to the interaction between learner characteristics and support characteristics. Research within the aptitude-treatment-interaction tradition revealed strong interactions between individual learner characteristics and instructional interventions (Snow, 1986; Snow & Swanson, 1992). This also pertains to support devices. Clark (1991) demonstrated that both too much or not enough support may be detrimental to learning.

A second development pertains to the delivery of support. Technological evolutions and especially the development of so-called pedagogical agents may provide possibilities to individualize support and encourage learners to use it. Pedagogical agents are, by definition, animated characters designed to operate in an educational setting for supporting or facilitating learning (Shaw, et al., 1999). They can adapt their support to learning paths of students and provide students with nonverbal feedback (Grégoire, Zettlemoyer, & Lester, 1999; Johnson, Rickel, & Lester, 2000).

Pedagogical agents have been primarily described and studied from a technological perspective (Johnson et al., 2000; Johnson, Rickel, Stiles, & Munro, 1997; Lester, Voerman, Towns, & Callaway, 1997; Graesser, Wiemer-Hastings, Wiemer-Hastings, & Kreuz, 1999). Nevertheless, studies with a more learning-oriented perspective are beginning to emerge (e.g., Moreno & Mayer, 2000).

To consider the use of pedagogical agents in instructional design endeavors and to study their role in encouraging students to use help functions, a common instructional typology is needed to describe these agents. The first section of this article addresses this aspect. Different modalities and roles are described that are integrated in a “support-typology.” In the second section, currently available pedagogical agents are discussed. The support-typology is used to analyze these agents. In the third section, research on the
relationship between learning and pedagogical agents is reviewed. Finally, the discussion and conclusion deals with issues concerning pedagogical agents and proposes future research questions.

SUPPORT TYPOLOGY FOR PEDAGOGICAL AGENTS

Learning results from interactions between a student and a learning environment (Billet, 1996; Lave & Wegner, 1991). However, not all learners will engage in interaction and cognitive activities that are functional in the learning environment. Support may enable students to engage in more appropriate processing (Collins, Brown, & Newman, 1989).

Support dimensions

Elen (1995) proposed a scheme with five dimensions to describe support initiatives: amount, formal object, topical object, delivery system, and timing of support. Previously, adaptation of support to the individual needs of learners was mentioned. Learners differ with respect to the amount of support they need. The required amount depends on prior knowledge of students (Ross, Rakow, & Bush, 1980) and other learner characteristics such as students' aptitude and metacognitive skills (Clark, 1990). Clark distinguished three levels of support: (a) no support (only goal statement and information are provided), (b) activation (goal statements, information, and indications on how to process the information are provided), and (c) compensation (instruction takes the cognitive burden, cognitive processing is taken over from the learner). A gradual withdrawal of support is generally advocated (Collins, et al., 1989; Jonassen, 1996; Vermunt, 1992).

The topical object of support relates to different components of the task. For solving a complex task in a technological environment, the topical object of support can be the content of the task itself (e.g., biological diversity), the strategies for solving the problem (e.g., analyzing information), and working in the environment (e.g., handling or working with the technology). The formal object of support on the other hand relates to student variables that are supported. Support may be directed towards students' domain specific prior knowledge, metacognitive knowledge or motivation. Prior knowledge is supported by adding domain-specific information. Directing support towards the motivation of students may involve presenting a challenge (Lepper, Woolverton, Mumme, & Gurtner, 1993), while supporting
metacognitive knowledge implies highlighting the learning goals and functionalities of various support elements (Dillemans, Lowyck, Van der Perre, Claeys, & Elen, 1998).

The fourth dimension to describe support is the delivery system-dimension. The delivery system pertains to the means through which support is offered to the students. Support can be embedded in technological tools, made available through means of textbooks, or delivered by teachers or peers.

The last dimension pertains to the timing of support, the moment at which the support is delivered. van Merriënboer (1997) distinguished between information relevant to recurrent aspects (rules, procedures, prerequisites) and to nonrecurrent aspects (system, approaches, heuristics). Support for recurrent aspects should consist of just in time information and immediate feedback on the quality of performance of certain skills. Support for non-recurrent aspects on the other hand should consist of both information presented up front and delayed.

Role of the Instructional Agent

In an open learning environment learners are responsible for their own learning. To foster learning, instructional agents may provide resources and manage mediating interventions (Devine, 1994). Instructional agents do not transmit "knowledge," but help students achieve their learning goals.

Literature (Barab & Duffy, 2000; Collins, et al., 1989, Hannafin, Land, & Oliver, 1999; Jonassen, 1999; Mandl & Prenzel, 1991; Merrill, 1994; Roblyer, Edwards, & Havriluk, 1997; Salomon, 1994; Vermunt, 1992) suggests six typical roles for instructional agents:

1. supplanting: the instructional agents assume responsibility for the tasks and perform them for the learners. The learners observe the instructional agents while they perform the task (e.g., Salomon, 1994). This can be compared to what Clark (1998) called a "compensation" where (meta)cognitive activities are taken over for the learner;

2. scaffolding: the instructional agents perform those parts of the task that learners are not yet able to perform themselves (Collins et al., 1989; Jonassen, 1996). This might allow learners to perform on a level just above their current level, in their "zone of proximal development" (Vygotsky, in De Corte, Verschaffel, & Lowyck, 1994);

3. demonstrating: the instructional agents show how a task is performed after which they observe how the learner performs the task (Merrill, 1994);

4. modeling: the instructional agents show how a task is performed while revealing and explaining their reasoning process. The instructional
agents solve a task while they articulate how problems are solved, what strategies are used, and what mental models are necessary to understand the task (Jonassen, 1996);

5. **coaching**: the instructional agents provide hints and feedback, and activate the learner when the learner is performing the task. The instructional agents observe the learners when they are solving a task and provide guidance when students experience difficulties (Barab & Duffy, 2000), and

6. **testing**: the instructional agents test the learners' knowledge about certain aspects of the task to guide the learning process (Martens & Dochy, 1997).

An analysis of these different roles of instructional agents reveals four different modalities of support: (a) executing, (b) showing, (c) explaining, and (d) questioning. Each of the six previously described roles can be characterized by (a combination of) analytical modalities. For instance, if the role of the instructional agents is coaching, the support can consist of a combination of explaining and questioning. Executing means that the task is performed by an instructional agent for the learner. Learners do not have to perform the task themselves. The learners observe the instructional agent. Showing involves the demonstration of the task by an instructional agent. Afterwards learners perform the task themselves. Explaining involves an instructional agent who clarifies the task while the learner performs the task. Questioning means asking questions about the task that have to be answered by the learner.

These different modalities can involve either the whole task or parts of it. This also means that instructional agents can shift between different roles for different parts of the task. In Table 1, the different modalities and roles are represented as a cross table.

Table 1

<table>
<thead>
<tr>
<th>Roles</th>
<th>Executing part/whole task</th>
<th>Showing part/whole task</th>
<th>Explaining part/whole task</th>
<th>Questioning part/whole task</th>
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<tr>
<td>Supplanting / Scaffolding</td>
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<td>Testing</td>
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Support-typology

The support-typology enables description and comparison of pedagogical agents from an instructional design perspective. It was elaborated by integrating the different support dimensions and the different roles of instructional agents. The elaboration implied adapting the initial dimensions as proposed by Elen (1995) to capture and analyze support delivered by pedagogical agents. The different dimensions appear as follows:

- **Object of support.** Support can be directed towards content, problem solving processes, metacognition, and handling technology. This dimension combines the topical object and the formal object dimension, since the distinction between these two objects is not always easy to make.

- **Learner control with respect to support.** An open learning environment by definition implies a great deal of learning control (Hannafin, 1995). However, since students seem not always capable of adequately choosing for themselves (Large, 1996; Williams, 1996), and given that reviews on learner control do not reveal a consistent positive effect (Friend & Cole, 1990; Goforth, 1994; Niemiec, Sikorski, & Walberg, 1996) this aspect requires further consideration. Pedagogical agents can control the support and take the initiative to provide it or students themselves may take this decision and request support.

- **Adaptability of support.** Not only the amount or quantity of support can be adapted to the needs of the learner, but also the object of support. Depending on specific needs of students, students might need support on a domain-specific level or on a metacognitive level for example. The change in quantity and object of support can be determined by either the program or by the learner.

- **Delivery modalities.** The delivery system of support is the pedagogical agent. This pedagogical agent can entail different delivery modalities, which might affect the effect of pedagogical agents on learning (Moreno, Mayer, & Lester, 2000). Pedagogical agents communicate verbally or nonverbally. Reeves and Nass (1996) indicated that students view the interaction with a computer (pedagogical agent) as a social interaction, in which three features are essential namely, (a) image, (b) voice, and (c) personalized language. A pedagogical agent has by definition, an image. Hence, this distinction is not included in the typology. However, the other two aspects will be. A distinction will be made between pedagogical agents using verbal and/or nonverbal language. With respect to verbal language pedagogical agents can use either text or speech to communicate
with the learner. Examples of nonverbal language are head nods and gestures to provide feedback. The pedagogical agent can communicate in a personal way, and engage in a dialogue, or in a less personal way, namely through a monologue.

- **Timing of support.** A pedagogical agent can deliver support either up front, by presenting for instance at the start of the interaction information the student will need to solve a task, or just-in-time during the execution of the task. It might also be that the agent provides delayed support by giving for example information about the process after task completion.
- **Support style.** This dimension refers to the different roles and modalities of an instructional agent (i.e., pedagogical agent).

Figure 1 provides an overview of the support typology.

![Support typology diagram]

**Figure 1.** "Support-typology" for pedagogical agents
ANALYSIS OF DIFFERENT PEDAGOGICAL AGENTS

Methodology

To identify pedagogical agents, a search was done on the ERIC- and PSYCINFO-databases, and the Internet (using the Google-search engine). Reference lists in articles generated through these searches were also used to find more information (snowball-method). This resulted in the agents presented in Table 2. Key words that were used to find information on pedagogical agents were “pedagogical agent”, “animated agent,” “agent and virtual reality,” “agent and multimedia,” “personal digital agent.” Only agents used in an educational setting were selected. This means that conversational agents and interface agents are not dealt with (Cassell et al., 1994). The analysis presented here gives an overview of the roles that pedagogical agents currently play in learning environments. The pedagogical agents are not presented in a specific order.

Description of the Different Pedagogical Agents

Adele (Shaw et al., 1999; Johnson et al., 2000; Ganeshan, Johnson, Shaw, & Wood, 2000) Adele supports distance learning in the domain of medicine and dentistry. She exists in three interaction modes. In the advisor mode, Adele observes the student when performing an action. If this action is inconsistent with standard practice, Adele will interrupt the students and suggest another action. In the practice mode, Adele provides advice only upon request of the student. In this mode, Adele does not interrupt the learner. A final mode is the examination mode. In this mode Adele does not give advice during the task, but provides feedback after task completion.

Adele uses the explanation and questioning modality in the advisor mode. She explains certain aspects to the students and may also question students. Her support is directed towards the content of the task, students’ problem solving process and working with the environment. Adele can adapt both the quantity and the object of support. This adaptation is determined by the learning path of the learner. Adele interacts both verbally and nonverbally with the students. Two-way verbal communication happens through speech and text. Nonverbal communication consists of facial expressions and gestures and is used to provide feedback to students. Depending on the interaction mode of Adele, either Adele takes the initiative to provide support (advisor mode); or the students take the initiative (practice mode). Support is delivered just in time and delayed.
Steve (Johnson et al., 2000). Steve is an acronym for Soar Training Expert for Virtual Environments. He demonstrates “skills” involved in a specific task in a virtual environment. The student can walk around in the environment and look at Steve’s demonstration from different angles. The student can also interrupt the agent and ask him to complete the task. When the students are performing the task themselves, they can ask Steve to show them what to do next. While Steve demonstrates part of the task, he explains what he is actually doing. In other words, Steve takes the role of modeling. While the student performs an action, Steve monitors this performance. His support is directed towards the content of the task, the problem-solving processes and working in the environment. Both quantity and object of support can be adapted to the learner needs. This adaptation of the support depends on students’ learning path. The initiative for support is initially taken by Steve and is delivered either up front or just in time, depending on whether Steve is modeling an activity or whether the student is performing him/herself that activity. Steve uses both verbal and nonverbal behavior to interact with students.

Herman the Bug (Lester, Stone & Stelling, 1999). Herman is an alien with human-like movements and facial expressions. Herman inhabits a learning environment called “design-a-plant” for the domain of botanical anatomy and physiology. He offers advice about the relation between plant features and environmental features, encouragement when students encounter difficulties and feedback on their choices while designing a plant. Herman coaches students. His support is directed towards the content of the task and the problem solving steps. Herman can adapt the content and amount of support to students’ steps. He delivers just in time support and controls support delivery. Herman the Bug communicates both verbally and nonverbally. He uses speech, facial expressions, and gestures to interact with the students.

Cosmo (Lester, Towns, & FitzGerald, 1999). Cosmo inhabits the Internet Advisor learning environment for the domain of Internet packet routing. Cosmo provides advice to learners on deciding how to ship packets through the network to specified destinations. Cosmo acts as a coach providing explanations on the content and problem solving steps. He can adapt quantity as well as object of support by analyzing the students’ problem status. Support can be delivered on the initiative of the agent or requested by the student. The support is delivered just-in-time.

WhizLow (Johnson et al., 2000; Grégoire et al., 1999). WhizLow lives in CPU City. This is a three dimensional learning environment, representing a motherboard with three principal components: the RAM, the CPU, and the hard drive. Students are given programming tasks. WhizLow carries out instructions given by the students. While performing this task, he traces misconceptions of the students and corrects them by providing advice. In other
words, WhizLow combines a supplanting and a coaching role. In his coaching role, advice is directed towards the content of the task. WhizLow adapts the amount of support to the misconceptions detected. The agent initially initiates support. However, students can ask for extra help. In such case, support is delivered just-in-time. WhizLow makes use of speech and gestures to deliver support.

PPPersona (André, Rist, & Müller, 1999). The PPPersona agent, is an animated agent for presenting online instruction. The agent guides the learner through web-based materials. By using gestures such as pointing the attention of students is drawn to particular elements in the presented information. PPPersona can be described as a demonstrator of information. Support cannot be adapted and the agent always initiates support delivery.

Jacob (Evers & Nijholt, 2000). The agent Jacob provides instruction and assistance for users' tasks in a virtual environment (e.g., tower of Hanoi). The user moves objects in a virtual environment and Jacob gives feedback while the user performs these activities. Jacob can also demonstrate the task. Jacob interacts with the student through text. He uses facial expressions to follow students' actions and uses gestures to perform the tasks. Jacob can take the initiative to provide just-in-time support to the student, but students may also request support from Jacob during task performance. The object of the support is the problem solving process.

Gandalf (Cassell & Thorisson, 1999). Gandalf is an expert in the solar system. Users may ask him questions about specific planets. Gandalf will virtually travel to these planets when a question is asked. Gandalf guides students through the material on the solar system by using speech and gestures. A student can ask Gandalf to give an explanation on specific elements of the solar system. The object of support is the content of the task. The learner initiates support delivery by asking Gandalf to explain (elements of) the solar system.

AutoTutor (Graesser et al., 1999). AutoTutor is designed to assist college students in learning the fundamentals of hardware, operating systems and the Internet in an introductory computer literacy course. AutoTutor presents questions to the students. The students' knowledge is tested by AutoTutor. The questions are asked in a text-based dialogue. The AutoTutor gives feedback to written answer of the student. The topical object of support is the content of the task and amount or object of the support cannot be adapted. AutoTutor nods his head or uses facial expressions.

The analysis reveals the following points (see Table 2 for a summary of the analysis):
• Most agents are designed to act as a coach. The agents provide hints and feedback to the learners, while learners are solving the problem. Sometimes demonstration of parts of the task is also included.

• Explaining is most frequently used as a modality, complemented by showing. The agent explains specific elements to the learners and sometimes shows how something has to be done or where the relevant information can be found.

• Pedagogical agents provide support on the level of the content and solving the problem. Two agents also provide support on the level of working in the environment. None of the agents provides metacognitive support or support learners in their monitoring and reflection processes.

• Except for two agents, all agents can adapt the amount of support they provide. Adele, Steve, Herman, and Cosmo can also adapt the object of support.

• Delivery modalities are very similar. All agents are technologically able to communicate both verbally and nonverbally. Most agents use speech to communicate. Adele uses both speech and text. The agents, except for PIPersona and Jacob, use both a monologue and a personalized way of communicating. All agents also use gestures to provide nonverbal feedback to the learners.

• Looking at who has control over providing support, it can be seen that in most case this is the agent, although some agents allow this control to be taken over by the learners.

• Just-in-time support is used frequently. Only seldom students receive support prior to or after solving the task. For PIPersona and AutoTutor, none of the possibilities is indicated in Table 2, since these applications relate to a continuous talking agent.

Research results

The analysis of existing pedagogical agents reveals that agents are already used in learning environments to support student learning. However, the question remains, to what extent these pedagogical agents are effective in supporting (aspects of) the learning process. Literature searches confirm
Table 2
Analysis of the Different Pedagogical Agents

<table>
<thead>
<tr>
<th>Table 2: Analysis of the different pedagogical agents</th>
<th>Role</th>
<th>Object</th>
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<td>Executing</td>
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<td>Showing</td>
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<td>Explaining</td>
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<td>Questioning</td>
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<tr>
<td>Supplanting</td>
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<td>Demonstrating</td>
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<td>Testing</td>
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<tr>
<td>Content</td>
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<tr>
<td>Problem solving</td>
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<td>Metacognition</td>
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<tr>
<td>Technology</td>
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</tbody>
</table>

| ADELE     |  | X | X |  |  |  | X | X |
| STEVE     | X | X |  |  |  |  | X | X |
| HERMAN    |  | X |  |  |  |  | X | X |
| COSMO     |  | X |  |  |  |  | X | X |
| WHIZLOW   | X | X | X |  |  |  | X | X |
| PPEPERSONA| X | X |  |  |  |  | X | X |
| JACOB     | X | X |  | X | X |  | X | X |
| GANDALF   | X | X |  | X | X |  | X | X |
| AUTOTUTOR | X | X |  |  |  |  | X | X |

| Total     | 1 | 4 | 8 | 2 | 1 | 4 | 1 | 7 | 1 | 8 | 5 | 0 | 2 |

<table>
<thead>
<tr>
<th>Adaptation</th>
<th>Delivery modality</th>
<th>Control</th>
<th>Timing</th>
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<tbody>
<tr>
<td>Quantity</td>
<td>Speech</td>
<td>Text</td>
<td>Monologue</td>
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<tr>
<td>ADELE</td>
<td>X</td>
<td>X</td>
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<tr>
<td>STEVE</td>
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<tr>
<td>HERMAN</td>
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<td>AUTOTUTOR</td>
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</table>

| Total       | 7 | 4 | 7 | 3 | 8 | 8 | 7 | 9 | 8 | 5 | 1 | ? | 1 |
that, although pedagogical agents only recently entered the field of education, some research has already been done on the relationship between learning and pedagogical agents.

Lester, Converse, Kahler, Barlow, Stone, and Bhoga (1997) performed a study to measure agents’ affective effects on learning. Five “clones” of *Herman the Bug* were studied. Clone one was fully expressive, and gave principle-based animated advice, as well as task-specific audio-advice. Clone two gave only principle-based animated advice; clone three gave principle-based but only verbal advice. Clone four gave task-specific verbal advice and clone five was mute. All other features remained identical. In all five conditions, the agent presented itself. The agent also presented the problem to the students. A pre and postknowledge test was administered. Additionally, a questionnaire was administered to assess the agent’s “affective” components. Results showed that all students performed significantly better on the posttest. This contradicts the hypothesis that pedagogical agents would distract learners and generate a mathemathantic effect or would hinder learning (Chandler & Sweller, 1991). The smallest increase in performance was for the students in the “mute” condition. The best results were achieved in the fully expressive condition. The results on the assessment questionnaire show a significantly higher score for the personal assessment of the agent (utility of the advice and feedback of the agent). Given also the increase on the posttest for the mute condition, Lester et al. concluded that there exists a persona-effect. The mere presence of an agent increases the scores. However, no control group (without an agent) was used in this study. Moreover, this persona-effect was not found by André et al. (1999), who created two versions of their learning environment, one with **PPP**ersona and one without. No differences were found between those two conditions.

Moreno, et al. (2000) compared two groups of students working in a discovery learning environment. One group had a pedagogical agent (*Herman the Bug*), while the other received text-based information. Tests were done for retention, transfer, and self-ratings. For the retention test no significant difference was found. For the transfer test a significant difference was found in favor for the group with the pedagogical agent. It also appeared that this group showed a greater interest and motivation. In a follow up study Moreno et al. (2000) experimented with pedagogical agents varying on the three features of social interaction mentioned by Reeves and Nass (1996): (a) image, (b) voice, and (c) personalized language. The studies indicated that the condition in which an agent with voice was used instead of text resulted in better results for retention and transfer. The sheer presence of an image of the pedagogical agent on the other hand had no effect. The kind of communication (dialogue versus monologue) influenced the results
for the retention test in favor of the dialogue mode (see also Moreno & Mayer, 2000). In other experiments, Moreno, Mayer, Spires, and Lester (2001) experimented with the type of image. The image of Herman was compared to a video-based image of a real person. No effects were found for this variable on retention and transfer.

In addition to these quasi-experimental studies two, more informal, evaluation studies can be mentioned. The first one relates to an evaluation of Steve (Johnson et al., 1998). It suggests that interacting with agents (i.e. Steve) in a virtual environment is perceived to be more natural than using conventional text-based tutoring interfaces. The second study deals with Adele (Shaw et al., 1999). Students indicated in a survey that they appreciate the support provided by Adele. Also, students preferred to hear a rationale only when they asked for it (practice mode). Nevertheless experience suggests that students do not ask for advice when given the choice.

Discussion and conclusion

In this contribution a typology was presented to analyze pedagogical agents from an instructional design perspective. This typology provides a common framework to describe and discuss pedagogical agents. The analysis based on a literature search reveals that most pedagogical agents act as coaches and provide support on the level of the content and problem solving. Most of the pedagogical agents are capable of adapting quantity and object of support to learners' action. It can be concluded that pedagogical agents are technically capable of adapting support to the needs of the learner by reacting to the learning path followed.

However, none of these pedagogical agents provide metacognitive support, while such support has been recognized as important (Hannafin, 1995; Shuell, 1992; Vermunt, 1992). The reason for the absence of metacognitive support might be explained by the origin of pedagogical agents. Pedagogical agents evolved from research on intelligent tutoring systems (Shaw et al., 1999), which are systems focusing strongly on the acquisition of domain specific knowledge (Epstein & Hillegeist, 1990; Shute & Psotka, 1996). These tutoring systems were developed, starting from teaching goals and aiming at how to replace a human tutor by an intelligent tutoring system (Derry & Lajoie, 1993). These tutoring systems mostly work with well-structured problems for which only one solution exists. The analysis of pedagogical agents demonstrates that, even now, most agents are used in situations that do not require students to solve complex problems but rather procedural tasks for which one solution exists (e.g. Jacob, PPersona).
develop a pedagogical agent that is able to operate in open learning environments in which students have control over their learning and work on a complex task, a different perspective might be indicated. Rather than starting from a teacher-oriented perspective (how to model a good tutor), a student-oriented perspective might be advocated. Analyzing students' needs while working on complex tasks, rather than analyzing tutor behavior, might help to reveal that students mainly need metacognitive support and to develop such support by the pedagogical agent. Rather than starting from focusing on the acquisition of domain specific knowledge, and representing a complete domain-model, metacognitive processes could be focused upon to enable students to monitor their own learning process.

Pedagogical agents operating in open learning environments and delivering support on a metacognitive level, might encourage learners to make more ample and deliberate use of support in open learning environments. Hill and Hannafin (2001) for example argued that students lack the necessary skills to monitor their learning and to make appropriate choices with respect to support devices in the learning environment. In any case, working with complex tasks makes it impossible to represent a whole knowledge domain (Derry & Lajoie, 1993).

While research with respect to intelligent tutoring systems focused on whether these systems were a "good" replacement of a human tutor (e.g., Schofield, Eurich-Fuker, & Britt, 1994), research on pedagogical agents would then focus on the influence of these agents on (aspects of) the learning process, taking into account research findings with respect to specific agent characteristics (Lester et al., 1997; Moreno et al., 2000) as well as specific learner variables (Shaw et al., 1999).

In summary, given the technological possibilities of these pedagogical agents and drawing lessons from the intelligent tutoring system-research, pedagogical agents do have possibilities for supporting learners when working with complex tasks in open learning environments. The potential of these pedagogical agents offer opportunities that should be grasped.

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