

# Building a Social Conversational Pedagogical Agent – Design Challenges and Methodological approaches

Agneta Gulz<sup>1,2</sup>, Magnus Haake<sup>2</sup>, Annika Silvervarg<sup>1</sup>, Björn Sjöden<sup>2</sup>, George Veletsianos<sup>3</sup>

<sup>1</sup> Linköping University, Sweden

<sup>2</sup> Lund University, Sweden

<sup>3</sup> University of Texas at Austin, U.S.A.

## ABSTRACT

This chapter discusses design challenges encountered when developing a conversational pedagogical agent. By tracing the historical roots of pedagogical agents in Intelligent Tutoring Systems (ITS), we discern central developments in creating an agent that is both knowledgeable and fosters a social relationship with the learner. Main challenges faced when attempting to develop a pedagogical agent of this kind relate to: i) learners' expectations on the agent's knowledge and social profile, ii) dealing with learners' engagement in off-task conversation and iii) managing potential abuse of the agent. We discuss these challenges and possible ways to address them, with reference to an ongoing Research & Development project, and with a focus on the design of a pedagogical agent's visual embodiment and its conversational capabilities.

## 1. INTRODUCTION

### 1.1 Conversational Pedagogical Agents

In this chapter a “pedagogical agent” refers to a computer-generated character employed in an educational setting in order to fulfill pedagogical purposes. Such agents (or characters) can serve numerous pedagogical roles (Chou, Chan, & Lin, 2003; Baylor & Kim, 2005; Haake & Gulz, 2009). For instance, they have been presented and studied as instructors, coaches, tutors, and learning companions.

The concept of an “agent” denotes an entity with some degree of “intelligence” and capacity for autonomous action. Agents, or intelligent agents as used within the computer science discipline, refer to a *computer programs* that can “act” on their own (i.e. autonomously). When referring to “pedagogical agents” in today's educational contexts, it is also assumed that the agent has a corresponding *visual representation*. *Conversational* pedagogical agents refer to a subgroup of pedagogical agents, namely those that can engage in a conversation with a learner, through dialogue, and, often through elaborate body language movements including gestures, facial expressions, etc.

In this chapter, we focus on conversation via natural language, and limit our treatment to text-based interaction (typed conversation via the keyboard). Thus, we do not discuss the challenges and potentials surrounding speech recognition and production. We also exclude complex non-verbal interaction (often explored in Embodied Conversational Agents research (e.g., Cassell, Sullivan, Prevost, & Churchill,

2000; Ruttkay & Pelachaud, 2004), where the agent's body is used for demonstrating, showing, pointing, and for giving feedback via gestural and emotional expressions. We discuss *animated pedagogical agents* where the visual animations are less complex, mainly aimed at making the agent appear more life-like and appealing.

## 1.2 Chapter Outline

We begin our discussion by tracing the historical roots of pedagogical agents in the *Intelligent Tutoring Systems* (ITS) paradigm, and discussing two central lines of development that have transformed agents from the nonsocial and impersonal characters of the past to the tangible, social and personal pedagogical agents of today: i) development of their visualization and embodiment and ii) development of their conversational capacities. These developments, we argue, carry with them important potential, as well as challenges, for research and development within the field.

In section 3, we present an ongoing Research & Development (R&D) project within the pedagogical agent domain – a web-based game focusing on mathematics learning for children – which serves to illustrate and contextualize our discussion.

In Section 4, we present the guiding framework that we use for designing and researching the project: *the Enhancing Agent-Learner Interaction framework (EnALI)* (Veletsianos, Miller, & Doering, 2009).

In section 5, we discuss central challenges that we hold as being common in pedagogical agent design and development endeavors:

- i) how to deal with students' (often heightened) expectations regarding pedagogical agents' knowledge and social competencies (including the problem of setting proper constraints),
- ii) how to deal with students' varying degree of engagement in social interaction with the pedagogical agent, and
- iii) how to deal with the risk of verbal abuse known to arise when students interact with conversationally-capable pedagogical agents.

We illustrate these challenges and possible ways to address them, with reference to our ongoing project and with reference to the EnALI framework. The list of challenges above is of course not exhaustive or applicable to *all* pedagogical conversational agent projects. Still, we consider them as representative of main issues that are likely to occur when developing pedagogical conversational agents. Numerous design decisions and challenges are involved in the design of agent-based educational software such as the one we will discuss. A complete list of all these design decisions would hardly be useful for readers. What *is* useful however, is the example of how one can reason about dealing with the complexity of decisions within design frameworks and still make progress towards a small number of well-defined, educational goals.

Our hope is that our discussion will inspire and benefit researchers and designers within the field who face similar issues. Our overall goal is to demonstrate how the field of conversational pedagogical agents represents a unique combination of theory and research intertwined with practice.

## 2. BACKGROUND

### 2.1. Intelligent tutoring systems

The development of pedagogical agents within digital learning environments finds its historical origins in *Intelligent Tutoring Systems* (ITS), which can be traced back to the early 1970's (Laurillard, 1993;

Wenger, 1987). A crucial step towards the development of ITS is often credited to a landmark paper by Carbonell (1970) where the concept of (human) *intelligence* was ascribed to an artificial system assisting a learner in an educational context. This system, called *SCHOLAR*, tutored students on South American geography by posing or answering questions via natural language in text format (*ibid.*).

An intelligent tutoring system exhibits certain characteristics and skills recognized in a *human tutor* such as being able to survey a student's learning progress and provide feedback to relevant actions, including contextual advice and support for problem solving within the learning environment (Laurillard, 1993). Furthermore, as frequently held forth through its history, an ITS allows for *individualization*: it adapts to individual students through various actions, such as offering help on request or recognizing the kinds of mistakes that a learner frequently makes in order to provide personalized feedback (*ibid.*). Individualization in this sense is, however, strictly performance-based and not aimed at establishing a social relationship with the student. *Personal interaction* is absent, and therefore, students do not develop personal relationships with virtual tutors. The *classic* ITS is an impersonal, non-social and abstract pedagogical agent whose sole purpose is to tutor.

In the 1990's this scene changed radically. A new generation of pedagogical agents entered the arena. This development can be ascribed to significant technological developments within two domains: the *visual embodiment area* and the *dialogue systems area*. These agents have been characterized as personal and relational artifacts. Next, we will describe how visual embodiment and dialogue systems have developed and what these developments mean for today's pedagogical agents.

## **2.2. From ITS to present-day pedagogical agents**

### *2.2.1. Visualization and embodiment*

Imaging and video techniques progressed rapidly during the late 1980's and the early 1990's. Present day pedagogical agents are – in contrast to classical tutoring systems – *visually embodied*, and often animated. They have a face and often a body or torso and are usually humanlike in their appearance.

This makes a modern pedagogical agent more tangible and less abstract than a classical ITS, which in turn increases the likelihood of learners approaching agents as *social entities* and as *personas* (Lester et al., 1997). The visual dimension of pedagogical agents is a powerful means for engendering affordances for social interaction, since it contributes strongly to the experience of a *character with a personality* (Isbister, 2006; Gulz & Haake, 2006) rather than simply a computer artifact. Such effects have recently come in the forefront of the pedagogical agent field. For instance, researchers have investigated the extent to which learners stereotype pedagogical agents and the degree to which such behavior impacts learning (Veletsianos, 2010).

The visual dimension is also a powerful tool for exploiting pedagogically central phenomena such as social models and identification. A social model, or role model, can influence attitudes and motivation as well as learner behaviors (Schunk, 1981; Bandura, 1986). A large set of studies show that pedagogical agents can function as (virtual) social models and similarly influence attitudes, motivation and learner behavior (Baylor, Rosenberg-Kima, & Plant, 2006; Kim, Wei Xu, Ko, & Llieva, 2007; Baylor, 2009; Gulz & Haake, 2010).

A particularly effective social model is either (a) one that is similar to the observer in significant aspects – so that the observer can identify herself with the model – or (b) one representing someone whom the observer aspires to be like. One key factor in this discussion is the visual appearance of the social model (Bandura, 1986), since appearance carries important and immediate information regarding an individual's gender, age, status, ethnicity, style, etc. This applies to human beings as well as to anthropomorphic

agents. Another visual factor that matters for the potential effectiveness of a social model is visual attractiveness. For a discussion of this, we refer to Baylor (2009) and Gulz & Haake (2010).

In other words, the visual design of a pedagogical agent is far from a cosmetic or surface aspect (Veletsianos, 2007). The choice of visual design of an agent can have considerable pedagogical consequences as a result of its potential function as a social model. A well-chosen visual design can positively impact learners' attitudes towards and interests in a subject (Baylor et al., 2006; Kim et al., 2007; Plant, Baylor, Doerr & Rosenberg-Kima, 2009; Gulz & Haake, 2010).

It can also significantly impact learners' *self-efficacy beliefs*. These are beliefs in one's capacity to accomplish certain tasks in a certain domain, which in turn are a predictor for actual success (Bandura, 2000). A number of studies within the domains of mathematics and technology, show the importance of the visual design of a pedagogical agent (most notably in terms of gender, ethnicity, age, and "coolness") for positively influencing learners' self-efficacy beliefs (Baylor, 2009; Kim, Baylor, & Shen, 2007; Baylor & Plant, 2005).

Overall there is growing evidence that the visual design of virtual characters effects actual accomplishments within a subject domain (Yee & Bailenson, 2007; Yee, Bailenson, & Ducheneaut, 2009). For a recent overview of the importance of visual design in pedagogical agents see Baylor (2009). In her review Baylor underlines that the *presence of a visual character* in a computational system as well as the character's *specific visual appearance* are two critical features for the design of an effective pedagogical agent – regardless of its underlying level of computational functionality.

Pedagogical agent visual design is not without challenges however: lack of analysis of visual design decisions can lead to pitfalls such as activating misleading expectations (Haake & Gulz, 2008) and unintentionally reproducing social stereotypes (Baylor, 2005).

#### 2.2.2. Developing conversational capacities

The first well-known conversational agent is *ELIZA*, which simulated a Rogerian psychotherapist (Weizenbaum, 1966). *ELIZA* is an example of what is today usually referred to as chatbot, a system with the goal to appear humanlike and engage in social conversation regarding a wide range of issues within an unrestricted domain. Many attempts to build conversational agents followed but the area subsided in the beginning of the 1980s due to the complexity of natural language processing, the problem of representing world knowledge, and the lack of research on connected dialogue and discourse.

The late 1980's and 1990's saw breakthroughs in these areas (cf. Grosz & Sidner, 1986; Smith, 1992; Jönsson, 1997), which in turn led to development of new kinds of dialogue systems which were more task-oriented and dealt with restricted domains, such as *Galaxy* (Goddeau et al., 1994; Seneff et al., 1998) *RailTel* (Bennacef et al., 1996) *TRAINS* (Allen et al., 1995) and *Verbmobil* (Alexandersson, Maier & Reithinger, 1994). These systems were considerably more powerful in the way they could efficiently and smoothly assist a person in solving a task. Furthermore, these systems (a) relied on reasoning mechanisms dealing with knowledge of the domain, the task, the user and the dialogue (Flycht-Eriksson, 2003), and (b) often used complex strategies for dialogue management to achieve fluid interactions and mixed initiative between user and system.

A special type of these task-oriented dialogue systems are tutoring/tutorial dialogue systems that combine the pedagogical functions of intelligent tutoring systems with natural language conversations. In this type of system, natural language conversation is used mainly for a tutor to ask questions, ask a student to elaborate on his/her examples, elaborate on answers, provide further information, summarize answers, correct misconceptions, or provide hints and directions. For examples of research in this area see

Graesser, Wiemer-Hastings, Wiemer-Hastings, Kreuz & the Tutoring Research Group (1999), Graesser, Chipman, Haynes & Olney (2005), and VanLehn et al. (2007).

More recently, there has been a revival of *chatbots* developed for various purposes and deployed on the Internet, most frequently developed using the AIML architecture (<http://www.alicebot.org/aiml.html>). A common use is their deployment as information-providing agents on websites, but these have also been used in education, automatic telephone help desks, business and e-commerce.

Chatbot systems usually have shallow or no understanding of the dialogue, but work by processing the surface text using keyword spotting, pattern matching and information retrieval techniques. They also have no knowledge representations about the world, but can “talk” about a multitude of topics in a dialogue that usually consists of question and answer turns. Connected discourse is limited and the initiative usually belongs either to the user or to the system. However, with improved methods for data mining and machine learning, and the availability of corpora and robust linguistic annotations standards like XML, development and application of chatbot systems are becoming more practical (Shawar & Atwell, 2007).

In between chatbots and task-oriented dialogue systems, a new system category emerged, termed Virtual humans (Traum, Swartout, Gratch, & Marsella, 2008). The main differences between these three systems are presented in Figure 1.

*Figure 1. Characteristics in Chatbots, Virtual Humans, and Task-oriented dialogue systems.*

Virtual Humans are agents that *have a goal of both being humanlike and being able to complete tasks in an efficient manner*. From a pedagogical perspective, this development introduces unique new potentials and challenges. Connected and mixed-initiative dialogue, along with the possibility to keep track of a dialogue history, enables educators to develop learning scenarios that capitalize on humanlike interaction (e.g. by enabling learners to discuss issues of historical significance with historical agents). They also offer possibilities to combine elements from task-oriented dialogues in restricted domains with elements from broader, but shallower, dialogues of the kind used in chatbots. At the same time, the knowledge representations and processing of the dialogue can be less extensive and simpler than in traditional task-oriented dialogues.

A central point to make here is that *Virtual Humans* offer enhanced possibilities for simulating human conversation due to the possibility of shifting between task- and domain-oriented conversations, on the one hand, and a broader and more socially oriented conversation, on the other hand. An important implication of this combination of task- and domain-oriented conversation with social conversation is that it opens up the possibility for a student and a pedagogical agent to engage in what Bickmore (2003) calls “relation-oriented conversation”. To some extent this development parallels the development of visual embodiment of pedagogical agents. Both these developments amplify the affordances of a pedagogical agent as someone to have a *personal relationship with*.

### **2.3. Intentional relation building**

The basis for relation building between student and agent presumably lies in the media equation, formulated by Reeves & Nass (1996) who discovered that humans tend to respond to media, including computer artifacts, in manners that are surprisingly similar to how humans respond to other humans. With present-day development of pedagogical conversational agents – visually embodied in a humanlike shape and entertaining a humanlike conversation – the human disposition to respond socially to media is *intentionally* exploited as, in education “the establishing of personal relationships is absolutely crucial”

(Bickmore, 2002, p. 1) Pedagogical conversational agents also enable individuals to introduce crucial elements of social context and personal relations, regarded as primary conditions for cognitive and social development (John-Steiner & Mahn, 2003), into a digital learning environment (Baylor & Kim, 2005; Gulz, 2005; Hall et al., 2004; Johnson, Kole, Shaw, & Pain, 2003; Paiva et al., 2004; Wang et al., 2008).

It is within this context that we introduce an ongoing R&D project in the next section. The project focuses on the design and development of an educational math game that includes a pedagogical agent. The agent shares similarities to a traditional ITS, in that it is abstract (minimally embodied) and strictly domain- and task-oriented in its interactions with the learners. The project sets out to develop a present day pedagogical conversational agent, by means of *visual embodiment* and *conversational capacities*. The goal is to enable effective interaction and purposeful learning, within the context of an agent architecture that fosters agent-learner relationships.

### 3. THE ILLUSTRATIVE R&D PROJECT

#### 3.1. The original game: An educational math game with a teachable agent

The math game on which the present R&D project is based, has been developed by Pareto and Schwartz (Pareto, 2004; Pareto, Schwartz, & Svensson, 2009). The educational content of the game is basic arithmetic with a particular focus on base-10 concepts. The math game contains several different 2-player board games that intertwine game play with learning content.

The *pedagogical agent* in the game is a *Teachable Agent* (TA) (Biswas, Katzlberger, Brandford, Schwartz, & TAG-V, 2001). This is a class of pedagogical agents that build upon the pedagogy of *learning by teaching* (Bargh & Schul, 1980) – a pedagogy that has proven to be beneficial for learning in an educational game context (Chase, Chin, Oppezzo, & Schwartz, 2009).

In this game students teach their agents to play the math games, and depending on the quality of the student's teaching, the TA constructs a mathematical model by means of artificial intelligence (AI) algorithms. Thereafter, the TA's mathematical knowledge is continuously reflected in its skill to play the different board games. The game includes two modes. In the first mode, the student demonstrates to the agent how to play the game, and in the second mode "tries to play" by proposing cards that the student can either affirm or replace with another card. In both modes, the agent poses multiple-choice questions to the student that relate to game happenings. Proper (or improper) answers impact corresponding skills in the teachable agent via the AI algorithms. We will refer to the multiple-choice questions module as "on-task conversation," acknowledging that this is a limited and rudimentary form of "conversation,"

-----INSERT FIGURE 2 HERE -----

*Figure 2. On-task conversation in the original game. See David's agent in the upper left.*

As seen in Figure 2 (where two agents play against each other in the "Try and play" mode), the original game includes a very basic visual embodiment of the agent in the form of a simple iconic static image.

-----INSERT FIGURE 3 HERE -----

*Figure 3. Enhancements to the original math game: visual embodiment and conversational capacity.*

The present R&D project involves development of visual embodiment and capacities for conversation (Figure 3). Note that the two areas being added to the original agent of the game are those that were

presented in Sections 2.2. and 2.3. With these developments we strengthen the agent's affordances as "a persona" and "a social entity". It should be noted, however, that the media equation (Reeves & Nass, 1996) predicts that the agent in the original game will be approached as a social entity, even though it does not allow any sophisticated interaction and is visually rudimentary.

According to the media equation, minimal social cues from a computer artifact, such as a pair of eyes, a face, linguistic output of some kind, leads users to spontaneously respond and make attributions to the artifact *as if* the artifact is a social entity. For example, students who played the original game made the following remarks about the teachable agents, indicating that they applied human attributes to them (Lindström, Haake, Sjöden & Gulz, in press).

- "What is **she** doing? Is **she** nuts?!"
- "My agent is **pretty smart**, but **he** is not in the lead now"
- "The most important thing is not the outcome, **the most important thing is that the agents are having fun!**"

### 3.2. Visual embodiment of the teachable agent and a novel conversational module

In the system under development, the original agent image (to the left in Figure 4) has been replaced, via iterative development and testing, with more elaborated visual figures. A first set can be seen to the right in Figure 4, and a second iteration of some of them in Figure 5. Figure 6 provides a view of an agent when a student is playing the math game against the computer.

Thorough user testing with the target group in question is essential in these iterative processes, given the importance of visual features for establishing affinity and for role-modeling and identification as described in section 2.2.1.

-----INSERT FIGURE 4 HERE-----

*Figure 4. The embodiment of the pedagogical agent in the original math game to the left with some of the novel visual characters to the right.*

-----INSERT FIGURE 5 HERE-----

*Figure 5. Second iteration of agents for the math game.*

-----INSERT FIGURE 6 HERE-----

*Figure 6. Novel embodiment of the agent in its game context. Note: The word "Dator" under the upper right icon is Swedish for "Computer".*

Note that we explicitly avoid a naturalist or even semi-naturalist style for the pedagogical agent representation. The main reason is that we want to downplay expectations that students may have relating to the agent behaving and conversing *just like* a human being: a conflict between the abilities of an agent and the learners' perception of these abilities, has been shown to cause frustration in a learner.

Dowling (2000), with reference to Masterton (1998), claims that many users “express a higher tolerance of the limitations of a ‘character’ that is represented in less detail, for instance through cartoon-like graphics.” (*ibid.*, p. 30). Likewise, Dehn and van Mulken (2000) review studies that indicate that agents with a more naturalistic visual appearance can indeed hamper learning by misleading the learner to believe that the agent resembles human beings in other cognitive and emotional aspects as well. They may, for instance, expect empathy from the agent or expect conversational capacities, that the agent does not live up to, leading to disappointment and frustration (Veletsianos, Scharber, & Doering, 2008).

The second main development – the focus of this chapter – consists of a module that allows the student to engage in free-form conversation with the agent between game sessions (vis a-vis a conversation that is steered by multiple-choice options, see Figure 3).

Whereas we refer to the multiple-choice format conversation while playing a particular board game as *on-task* conversation – we refer to the module for free conversation with the agent in the form of a chat window as *off-task* conversation. In turn, we distinguish two off-task conversation categories with respect to the topic or content<sup>1</sup>.

- *Off-task/on-domain* conversation is free conversation relating to the math game, mathematics in general, and school. Conversations that focus on how fun or boring certain board games were or about whether one thinks mathematics is difficult or not, would classify as off-task/on-domain conversation.
- *Off-task/off-domain* conversation can be about any topic other than the ones above. For instance conversations about music, being tired, sports, and food are classified as off-task/off-domain conversations.

The underlying dialogue architecture for a pedagogical agent that will handle such off-task conversation, together with topics that relate to the specific math games being played, has to be a combination of a chatbot-like system and a task-oriented ITS-like system (compare Figure 1).

In our system we are implementing the agent’s ability to engage in off-task conversation as a mixed-initiative dialogue strategy in order to allow both the agent and the user to direct the dialogue (e.g. by introducing new topics and posing questions). The agent keeps a history of the utterances in the dialogue, both in the current and previous sessions. This gives us a possible tool for obtaining a balance between on-domain and off-domain topics in the off-task conversation. For instance, the pedagogical agent may attempt to bring the learner back to the task by (re)introducing particular topics of conversation: if the student has persisted in discussing music, the agent can ask about school-related music lessons with the aim to guide the subject back to school-related topics.

Next, we expand on the underlying *reasons* for introducing off-task conversation in a pedagogical agent system by discussing potential pedagogical benefits. We start by looking at human-to-human teaching and the combination of on-task and off-task conversation in that context.

### 3.4. Potential educational benefits of off-task conversation

In traditional teaching situations such as lessons, lectures, tutorials, etc., there is always a mixture of *on-task* conversation that strictly pertains to the subject content and tasks of the lesson, and some *off-task* conversation. Instructors regularly digress from the content they are teaching: they may bring up a matter of general interest, comment on their own personal relation to the subject of the lesson, share a joke, and

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<sup>1</sup> These distinctions are important when it comes to evaluating the pedagogical function of off-task conversations and optimizing their potential for promoting actual learning.



so on. In fact, it is unusual to find a teacher who is completely focused and does not at all deviate from the task and topic of a lesson.

A number of pedagogical motives exist for including opportunities for off-task conversations in a digital learning environment.

- Off-task conversations may encourage emotional engagement and create additional possibilities for remembering content. This is supported by findings that brain processes of memory coding and storage are stimulated by emotional engagement (Hamann, 2001). Nevertheless, this is not to say that all off-task interactions are equally engaging. For instance, “small talk” can promote trust and rapport-building, and at the same time bring in task-related information (Bickmore & Cassell, 1999; Bickmore & Cassell, 2000). An example from a real classroom would be a chemistry teacher who engages her students in discussion about school and relates an anecdote about the time she caused a fire during a laboratory lesson as a student. Kumar, Gweon, Joshi, Cui & Rosé (2007) conducted an experiment along this line of thought with a dialogue agent within the mathematics domain, where the agent accompanied student pairs in collaborative learning via a chat. The agents came in two versions: one with cognitive support agents only, and one with both cognitive support agents and social dialogue agents. The latter were designed to show personal interest in the students by asking them to reveal their personal preferences about extra-curricular domains. The student preferences were then used as input when the math problems were constructed. If one student answered that she would prefer a long car ride to a long flight, and the other student in the pair responded that books are more amusing than movies, the math activities presented to these students would include a car ride and books. The intention was that the social dialogue should give students the impression that the agent takes personal interest in them. Results showed that the addition of the social dialogue agents had a strong positive effect on the attitude that students displayed towards agents as well as a slight positive effect at learning outcomes. The authors argued that “social prompts are not just extraneous entertainment, but can affect student’s attitudes and behavior.”
- Off-task conversation can make a learner feel more comfortable, relaxed and at ease with a learning task or topic. It can even help to release mental blockages that beset some students with regard to certain educational material, for example mathematics or technical subjects (van Mulken, André, & Müller, 1998). Math anxiety for instance, is a feeling of tension, apprehension, or fear that interferes with math performance and is a well-documented phenomenon (Hembree, 1990). The potential exists to use an agent’s off-task conversation to encourage a more relaxed atmosphere when learning mathematics. An agent can also act as role model for ways to cope with difficulties (cf. Schunk, Hanson & Cox, 1987).
- Finally, it has often been suggested that off-task conversation of a social and relational kind, can result in increased motivation or engagement with the task and domain in question. For instance, Ryu & Baylor (2005) hold forth “the ‘*Engaging* factor’ or ‘the *positive social presence* of the agent’ as it is ‘there’ for the learners and motivating them” (p. 26). In turn, such motivating effects – gained from the social dimensions of interacting with a pedagogical agent – may affect learning outcomes in terms of improved understanding, memory, problem solving, etc. (e.g. Lester *et al.*, 2000; Moundridou & Virvou, 2002; Johnson *et al.*, 2003). According to André and Rist (2000), a person possibly learns more about a subject matter if he/she is willing to *spend more time* with a system. Moreno, Mayer, Spires, and Lester (2001) suggest that a *social* agency environment built around a conversational pedagogical agent will encourage learners to *make a stronger effort* to understand material.

In sum, by adding an off-task conversation module to the original game and pedagogical agent, we simulate a natural part of traditional educational settings, hoping that this will have positive effects on the motivational qualities of the game. In addition we set out to explore whether the conversational module

can be the basis of pedagogical interventions to affect students' math self-efficacy and attitudes towards math as a school subject.

## 4. GUIDING FRAMEWORKS

### 4.1 The Enhancing Agent-Learner Interaction (EnALI) framework

Researchers have long called for a refined approach to the design of virtual agents (Dehn & van Mulken, 2000), and during the last few years pedagogical agent researchers have proposed a number of frameworks to enhance pedagogical agent implementations (e.g., Kim & Baylor, 2008; Woo, 2009).

In this paper, we use the *Enhancing Agent-Learner Interaction* (EnALI) framework (Veletsianos et al., 2009) to guide our work. The EnALI framework, consists of practical guidelines for the effective design of pedagogical agents that are in close alignment with design inquiry and practice, taking an encompassing view of design that addresses social, conversational, and pedagogical issues. These guidelines focus on enhancing agent-learner interaction, agent message, and agent characteristics and are presented in Table 1. We will return to these in the sections that follow.

*Table 1. The Enhancing Agent Learner Interactions (EnALI) Framework (from Veletsianos, Miller, & Doering, 2009)*

<i>Design focus</i>	<i>Guidelines</i>
1 User interaction	<p><i>Agents should be attentive and sensitive to the learner's needs and wants by:</i></p> <ul style="list-style-type: none"> <li>- Being responsive and reactive to requests for additional and/or expanded information.</li> <li>- Being redundant.</li> <li>- Asking for formative and summative feedback.</li> <li>- Maintaining an appropriate balance between on- and off-task communications.</li> </ul>
2 Message	<p><i>Agents should consider intricacies of the message by:</i></p> <ul style="list-style-type: none"> <li>- Making the message appropriate to the receiver's abilities, experiences, and frame of reference.</li> <li>- Using congruent verbal and nonverbal messages.</li> <li>- Clearly owning the message.</li> <li>- Making messages complete and specific.</li> <li>- Using descriptive, non-evaluative comments.</li> <li>- Describing feelings by name, action, or figure of speech.</li> </ul>
3 Agent characteristics	<p><i>Agents should display socially appropriate demeanor, posture, and representation by:</i></p> <ul style="list-style-type: none"> <li>- Establishing credibility and trustworthiness.</li> <li>- Establishing role and relationship to user/task.</li> <li>- Being polite and positive (e.g., encouraging, motivating).</li> <li>- Being expressive (e.g. exhibiting verbal cues in speech).</li> <li>- Using a visual representation appropriate to content.</li> </ul>

It is important to observe that these guidelines may overlap and influence one another. For instance, one guideline suggests that agents "maintain an appropriate balance between on- and off-task

communications” and another suggests that agents “establish [their] credibility and trustworthiness.” Notably, both on-task and off-task interactions can establish or shatter credibility or trustworthiness: correct on-task responses to learner questions and off-task remarks (e.g. remembering a learner’s name after an initial interaction) may establish rapport, while incorrect on-task responses to learner questions and off-task remarks at inappropriate times (e.g. when the learner is requesting assistance with an especially challenging aspect of a learning activity) may ruin the agent’s credibility.

## 4.2 Design based research

The methodology that we use to enhance pedagogical agent deployments is termed Design based research (DBR) and is a relatively new research methodology that aims to assist in understanding learning in context (Brown, 1992; Collins, 1992). Wang and Hannafin (2006, p.6) describe DBR as “a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories.”

DBR attempts to understand the “how” while valuing ecological validity and exploration in messy educational contexts. For instance, we ask, (a) how does pedagogical agent appearance influence the way agents and learners interact, (b) how do iterative modifications enhance learning, (c) and how does knowledge from this exercise inform theory and practice? More formally, DBR is a multi-step methodological approach aimed at enhancing learning and teaching processes by means of theory development, research in authentic and naturalistic environments, and the sharing of knowledge amongst practitioners and researchers (The Design-Based Research Collective, 2003). Phenomena are studied in their “messy contexts,” outside of experimental labs (Brown, 1992) because any insights gained from investigations undertaken in out-of-context environments have limited applicability in the classroom.

## 5. DESIGN CHALLENGES AND POSSIBLE WAYS TO APPROACH THEM

We identify four main design challenges that we confronted in the development process of the pedagogical conversational agent in the math game. The challenges in question all arise from the decision to develop the original agent into a social and personal kind of agent – by means of *visual embodiment* and an *extension of its conversational capacities*. These challenges are therefore likely to be faced by others who aim to develop the kind of pedagogical agent previously categorized as a “virtual human”:

1. **The challenge of student expectations regarding the pedagogical agent’s knowledge:** how to handle students’ expectations on the knowledge and *knowledge profile* of the pedagogical agent.
2. **The challenge of student expectations regarding the pedagogical agent’s social abilities:** how to manage students’ expectations on the *social profile* of the pedagogical agent.
3. **The challenges of students’ engagement in off-task conversation:**
  - a) how to manage students’ possible over-engagement in off-task conversation with the pedagogical agent,
  - b) how to manage students’ possible under-engagement in off-task conversation with the pedagogical agent.
4. **The challenge of abusive student comments:** how to manage the pedagogical agent’s responses to inappropriate or abusive user language without ending the conversation.

### 5.1. The challenge of student expectations regarding the pedagogical agent's knowledge profile

Students need to experience a pedagogical agent as *useful* for information purposes and for their learning task at hand (Veletsianos, 2010). A corresponding design challenge is to create a pedagogical agent that lives up to this task. However, this challenge applies to all pedagogical agents, including classical ITS systems.

According to the EnALI framework, a pedagogical agent should be able to promptly provide complete and specific information that is appropriate to the student's abilities, experiences and frame of reference. Again the corresponding design challenge is not unique to present day conversational agents but applies to classical tutoring systems too. However, when we introduce a pedagogical agent whose conversation capacities expands from the ability to engage in a limited, domain-specific and task-oriented conversation to also being able to engage in broader, humanlike conversation, the challenge of creating an *appropriate knowledge profile* becomes considerably more complex.

As soon as the pedagogical agent appears on the screen, and throughout the conversation, the student will develop expectations regarding the *agent's conversational abilities*. Can the agent discuss strategies of the math game? Can it tell whether it finds mathematics a boring subject? Can it discuss music? Can it give an answer to whether it has a best friend or not?

In our example system we need to handle students' expectations of the agent's conversational capacity as pertaining both to *on-domain* and *off-domain* content. Selecting its particular off-task knowledge areas – what it should be capable to talk about and not with the 12-14 year olds in the target group – is a non-trivial and challenging task in itself. Importantly, the R&D team (with a mean age of around 45) needed input from the target audience. This task especially important for off-task/off-domain areas, where the main purpose is to increase student engagement with the game and system (and hopefully have a spill-over towards the mathematical content of the game, attitudes to math, etc.) In order to decide which domains the agent should have knowledge on and be interested in, we collected information from the student target group in an iterative design-redesign process. In concrete terms, focus group interviews provide the input for a Wizard-of-oz role-play (where two students are engaged in a computer mediated, text based chat – one of them taking the role of the pedagogical agent). The collected data in iterations is subject to a dialogue corpus analysis, to provide input for the iterative prototyping of our conversational system. The dialogue logs are then analyzed together with the material from surveys and other focus group interviews.

Our first round of iterative studies and development was completed as follows: for the focus group sessions, twenty 13-14 year-old students played the game for 30 minutes. In these sessions, the agent was present and posed on-task questions. The students were thereafter split into four focus groups that discussed the agent's personality and interests, the agent's visual appearance and any additional information that they wanted to provide about the agent.

Regarding the latter we found it valuable to compare the outcome with the topics that the R&D group had suggested beforehand as probable desired topics for off-task conversation. The students discussed some of these topics (for example, off-task conversations about friends and school). We also discovered that the students did not discuss various topics that we originally thought they would discuss (e.g., film and traveling). In addition, students consistently proposed topics that the R&D group had not previously considered (e.g. sports, music, and computer games).

On the basis of the material from the focus groups, we developed a sketch of the agent's persona as a basis for a role-play activity, in which students simulated off-task conversations in the game (Wizard-of-Oz

study). Agent players were asked to act in accordance with the persona, and if dialogue topics occurred outside of the persona's knowledge scope, they were asked to improvise. The resulting 12 dialogues were analyzed, and again novel topics emerged.

Thereafter a system prototype was developed that was tested by another 38 representatives from the target group. After a short introduction to the system the students played the game for 10 minutes, chatted with the agent for 5 minutes, played the game for another 5 minutes, and chatted with the agent for 5 additional minutes. This was repeated with a revised prototype with the same group of students<sup>2</sup>. These two cycles of iteration led to a refinement and extension of the off-task conversational module. In sum, the user studies described allowed us to expand, revise, and refine the off-task/off-domain topics that we, as researchers and designers, had devised. The target group, acting as designers, helped refine the topics, language, and content used.

For the off-task/on-domain topics the situation is different. We have pedagogical motives for incorporating conversational topics that relate to the domain of mathematics: attitudes towards math, math self-efficacy, etc. However, the conversational architecture must be designed so that conversations on these topics are not perceived as strained in the conversations as a whole. Part of our approach to deal with this comes from our view on on-task conversation and off-task conversation as *interrelated*. The interconnecting factor is represented by the *agent*, which integrates selected on-domain knowledge with (limited) off-domain knowledge (i.e. the agent is an 11-year old student that goes to school and is learning to play the math game, but also has interests like music and sports that it pursues in its spare time). Even when the free conversation is primarily oriented towards off-task/off-domain topics, the agent can also comment on the *game play* (i.e. on-task/on-domain topics), as well as introduce off-task/on-domain topics related to school, math, the math game, etc.

We also introduced a dedicated use of anecdotes and narrative storytelling. As evidenced by the work of Bickmore and Cassell (1999; 2000), anecdotes and small-talk have a social and trust-building function even when the interlocutor is a virtual character. At the same time, the content of small talk can be designed to convey something *relevant about the subject domain*. For our agent we plan to include anecdotal material relating to school and mathematics (e.g., the agent telling a story about “my friend, who turned the math book upside down and found the homework to be very difficult”; or about “the other day in school when we had math and the teacher was explaining on the whiteboard but made a mistake and could not get the right answer, but I saw the mistake and could show him”).

One issues that we faced relates to the large number of human cultural domains that humans know at least something about – but that the agent will know nothing about, especially contemporary news. The challenge is to position an agent so as to minimize the friction between “pretty good knowledge on some cultural domains” (for instance TV-shows, computer games, being friends, sports, etc.) and “very limited or no knowledge on others” (for instance cooking, dancing, playing chess). Part of such positioning can be achieved by an appropriate visual embodiment. Using an embodiment that is devoid of naturalism serves to downplay expectations regarding the agent acting and responding *like* a human being. Appropriate dialogue strategies are another important means for addressing this challenge. One needs to handle different classes of the cases where the agent will not understand the student's input. That is, we needed to build a dialogue architecture that can use varied and appropriate responses, such as for instance, in the following cases: asking for clarification, indicate misunderstanding, move on with the conversation, etc. (Artstein et al., 2009; Traum, Swartout, Gratch, & Marsella, 2008).

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<sup>2</sup> For both prototypes two questionnaires were filled in by the students, one regarding the experience of using the learning environment and one regarding the experienced personality of the agent.

There is yet another sub-challenge that relates to the idea of combining on-task conversation, strictly targeted at a task, and off-task conversation of a broader and socially oriented kind: if a student finds the *social conversation* with an agent satisfying and engaging, a failure of the same agent to be of use to the student on on-task activities will also cause disappointment.

Finally, one may observe that the challenges of constructing an adequate knowledge profile need further refinement in the case of *teachable* agents. A TA is unusually straightforward as to what it appears to know about its assigned subject. It is the student's task to train it and the agent will explicitly convey *not knowing anything at all* about the learning domain. A TA is not an expert, nor does it belong to any other kind of authoritative pedagogical agents (Haake & Gulz, 2009), and thus there is no risk for student disappointment because the agent discloses that it "knows too little." But when – like in our project – the TA is engaged in task-oriented conversations *and* socially-oriented interactions, there may be a clash between student expectations on the pedagogical agent's knowledge as to the math game (not knowing much at all) and its knowledge of general subjects.

The present section has dealt with student expectations on *what* the agent can/will talk to the student about. We have discussed our approach of iteratively collecting data relating to our target population, and in the next section we discuss student expectations on *how* the agent can/will talk to the student.

## **5.2. The challenge of student expectations regarding the pedagogical agent's social profile**

From the very first time a student enters the learning environment, s/he will have expectations as to what kind of character the pedagogical agent will be. In comparison to the agent's knowledge profile, we refer to the agent's *social profile* as the manner in which its knowledge is being communicated. Not only does a student have expectations on *what* the agent can talk about to his/her but also on *how* it can and will talk to him/her.

These expectations are also linked to how the student perceives the agent's general personal features, for example in terms of it being a kind or a mean character, extrovert or introvert, humorous or serious, happy or sad, etc. In addition, for any interaction, humans seem to expect some degree of *consistency* with respect to such characteristics. They will not expect – and not appreciate – changes in a pedagogical agent's exhibited attitudes or moods that are random and inconsistent (Isbister & Nass, 2000).

Now, what kind of social profile of a pedagogical agent will be appropriate for a given setting can be hard to predict beforehand. Nevertheless it is an important challenge to address, since a good match between student expectations of an agent's social profile is likely to enhance the pedagogical objective of making the conversation engaging, encouraging and motivating.

Already in the beginning of the design process with our present system, we have an illustrative example of how the EnALI framework can be fruitfully combined with a design-based research strategy for contextualizing, and exemplifying, some of the EnALI guidelines. In the case to be presented we started out from the "Agent Characteristics" guidelines (see Table 1) that suggest that the agent should be credible and trustworthy, establish a role to the user and be polite and positive. Inspired by Wang et al. (2008), who argue specifically for the so-called "politeness effect", our focus for this example is on the politeness aspect. The design process in question can be described as follows: (1) making a raw sketch of the agent character, (2) using this sketch as a basis for preliminary design decisions by the research team, (3) refining the design decisions through focus group interviews with actual students and (4) discussing design implications of the outcome based on the focus group results:

- *Step 1:* Starting from the EnALI guidelines, we made a raw sketch of an "Agent character". A very first set of preliminary design decisions were taken, directed by our knowledge and experience from other pedagogical agent systems as well as from our experience as teachers and considerations about the

technical feasibility. Notably, we conceived of the pedagogical agent as being “overall positive, nice and polite” in its conversation, in line with previous suggestions.

- *Step 2:* The first sketch became subject of much discussion, which highlighted the complexity of the student-agent relationship in relation to our various research goals. We are interested in the pedagogical agent’s potential to influence students’ attitudes towards math, with respect to math self-efficacy as well as to the general attitude towards math as a school subject. At the same time, these are factors we want to be able to manipulate in order to make empirically-based decisions, for example comparing an agent which exhibits low math self-efficacy to one with high math self-efficacy. Results from previous studies proved too ambiguous to serve as an empirical basis for definitive design decisions in these respects, which is why we turned to focus groups to gather input from students.
- *Step 3:* We conducted focus group interviews with four groups of 4-5 teenagers each (13-14 years old), who had the opportunity to play the math game, look at agent images (Figure 4) and listen to material about the game. In these discussions the students reinforced some of our preliminary design decisions regarding the agent’s personal qualities, such that it should be friendly, curious, eager to learn, and like school. However, students insisted that the agent should not be too polite, but express some “attitude”. Interestingly, it could be inferred from the interviews that a “too soft, nice and polite” character seemed to elicit skepticism among the students, rendering the agent untrustworthy (for the age group in question). This is an example of how a particular user group may give input that diverges from general design guidelines (Veletsianos, Miller & Doering, 2009; Wang et al., 2008) which thus highlights the importance of involving target user groups in design.
- *Step 4:* We turned to possible interpretations, and design implications, of the result regarding the agent being “polite” versus “having some attitude”. One interpretation is that the preference for a somewhat “plucky” agent with a bit of an attitude simply is an expression of students wanting to have fun. On the one hand this could be a positive design feature because it may introduce some playful conflict between agents and students. But, on the other hand, an agent having an attitude could be quickly marked as confrontational and conversations could quickly escalate to abuse (cf. Veletsianos, Scharber, & Doering, 2008). Another interpretation is that by stating things like “She/he should be positive, yes, but not over-positive, she/he should have some attitude” or “She/he should be nice but also have some attitude”, the students are searching for an agent that does not return scripted, robot-like responses. The agent should not reply or react in the same way whenever the student types the same comment. This does not prevent the agent from exhibiting an overall positive attitude, but its behavior as well as its mood should vary. In the social conversations, the agent can vary its utterances. In short, given that there are multiple interpretations of the result we see a need to continue exploration of this topic with input from the target group. In particular we need to capture in more detail what “expressing some attitude” means for the target group, and to what extent it relates to unpredictability, interesting personality, sarcasm, humor, and so on.

In conclusion, our considerations about the pedagogical agent’s social abilities illustrate that a successful design depends a lot on informative input from actual students on which to make further iterations and implementations of the system. This is also what contemporary design-based approaches to educational technology enhancements suggest.

### 5.3 The challenges of off-task engagement

A third challenge relates to students’ level of engagement in *off-task conversation* with conversational pedagogical agents. There are actually two sub-challenges that are the opposites of one another. On the one hand: an off-task conversation can become *so engaging* that the student completely deviates from the learning task. On the other hand: a student can find off-task conversation completely uninteresting and therefore not (want to) engage in it at all.

### 5.3.1 The appeal of off-task conversation

There are examples of students becoming so strongly immersed in conversation with a pedagogical agent that they forego the learning task, as demonstrated by Veletsianos and Miller (2008). This appears as a possible drawback of deploying a module “too elaborated” for social conversation, as students come to focus more on the social interaction than the present learning goal. Relating back to the EnALI framework, there is surely a fine line between students being engaged and being immersed to the point of losing focus on the task. As stated in the EnALI guidelines (Table 1), it is important to maintain an appropriate balance between on- and off-task activities.

Our way to address this in the system under development is by dedicatedly bridging the gap between what is *clearly task-oriented* (playing the math game and having a conversation on this) and what is *completely unrelated to the task* (discussing the music style of a rock singer or saying one wants to go and buy an ice-cream) with the *in between* category. *Off-task/on-domain conversation* is social and free conversation *but on the math game, on math, on school, etc.*

By combining a basic chatbot system architecture based on AIML with dialogue management and dialogue history techniques used in dialogue systems, the agent can handle a mixed initiative dialogue and by taking the initiative also steer away from long off-domain conversations and reintroduce the learning task. The pedagogical agent can in this way (re)introduce particular subjects of conversation, drawing from its knowledge database. For example, if the student comments on something in “school”, the pedagogical agent can relate the fact that mathematics is a school subject and select between associated responses, such as for instance “I had a pretty good day at school, but it was a very long one. I was tired during the last lesson of the day (math). Did you have math today too?” This provides a tool to work on a balancing between on-task and off-task conversations between agent and student.

### 5.3.2 The non-appeal of off-task conversation

On the other hand, some students show very *little* interest in engaging in off-task conversation (Gulz, 2005; Veletsianos, 2009), and may experience off-task conversation as unnecessary and meaningless, taking time from the task. In a study with ninety 12-15-year-old school children from a Swedish secondary school (Gulz, 2005), 37 out of 90 said that they would prefer a pedagogical agent that was strictly task-oriented in its conversation rather than also engage in socially oriented off-task conversation. The arguments fell into four categories: i) off-task conversation with the agent would be *trying, tiresome and a nuisance*, ii) there is a risk of *getting distracted* by off-task conversation, iii) off-task conversation would involve doing *unnecessary or meaningless things instead of focusing* on what is important, and iv) minimal interest in developing a socially oriented relationship with a computer. Similar results of *diverging* attitudes towards agents’ off-task conversation have been presented by Bickmore (2003) and by Hall et al. (2004). In other words, the notion that social dimensions of virtual characters increase learners’ motivation and engagement may be less straightforward than is sometimes hypothesized (Gulz, 2005).

We tackle this challenge through various approaches. First, we constructed our system in such a way that it can detect a student’s lack of engagement in off-task conversation (which is relatively easy to determine from simply the amount of typed text and certain indicative comments or questions). The agent can then take the initiative to finish a conversation and return to the game: “Let’s play again”, “Do you want to play another game?” Another approach is to enable the learner to end the social conversation by adding a button to ‘return to game’ by which a student can chose to terminate an off-task conversation before the chat-time (pause-time) has passed.

### 5.3.3 Finding the balance and allowing flexibility for individuals

Some students are considerably more attracted to an agent that engages in off-task conversation than others. Simply placing preference for pedagogical agent engaging in off-task conversation against preference for a pedagogical agent not doing so is an oversimplification. The *amount* of off-task



conversation in relation to task-oriented conversation and the *kind* of off-task conversation are important parameters that can influence preferences. These parameters affect a learner's judgment of the value and worth of off-task interactions.

In fact, there is evidence that a pedagogical agents' engaging in off-task conversation can lead to a stronger focus on the task by the part of the students. In a study by Ai and colleagues (Ai, Kumar, Nguyen, Nagasunder & Rosé, 2010) student pairs interacted with one another within a collaborative software, where a conversational agent in the role of a tutor participated with the students in a chat. The conversational agent was presented in three different versions that differed in the amount of social behaviors and attitudes exhibited by the agent in the conversation. The non-social tutor agent was strictly task-oriented in its conversation, whereas the Low social and the High social agents differed in the frequency of bringing in socially oriented utterances in the conversation. Results showed that the students who interacted with the social agents focused more on the task rather than engaging in off-task conversations with each another.

The system that we develop includes off-task conversations that relate to the task at hand – these aspects we call off-task/on-domain. The agent can use this aspect of off-task conversation to boost the students' accomplishments– for instance the agent could say: “It would not have been easy to learn this without your help”, or “I never thought that math could be this fun, thanks to you”. The R&D project will explore how this can be used as a way to influence students' self-efficacy beliefs in math (cf. section 2.2.1 above).

In the off-task/off-domain conversation, very different kinds of topics can be discussed. It is expected that students are likely to have different opinions on the usefulness of this type of conversation and be differently willing to engage in it. As discussed above we will opt for design solutions that allow flexibility and choice in order to meet this challenge. Our rationale for this choice comes from the study mentioned above (Gulz, 2005), where students responded that the ideal, as they saw it, would be to be able to choose which agent they wanted to interact with: “Sometimes one would feel like talking more and chatting, but sometimes one would prefer an agent that is quiet and sticks to the task.” [...]; ‘It depends, sometimes I would like one that is talkative and social, but sometimes I cannot stand that and want to be spared from it’ (ibid. p. 413).”

## **5.4 The challenge of abusive student comments**

A fourth challenge relates to avoiding conversations in which students abuse the pedagogical agent (Branham & De Angeli, 2008; De Angeli & Branham, 2008). The EnALI framework suggests several guidelines for addressing this challenge. Relating to the agent characteristics, for example, the agent should display socially appropriate demeanor and representation and use a visual representation appropriate to the content.

Previously this challenge has been addressed by making the agent give very neutral responses to as student's verbal abuse. Veletsianos, Scharber, and Doering (2008) allowed the pedagogical agent respond to abuses by informing the user that foul language is inappropriate. This response however, resulted in continued abuse. Our current approach involves the pedagogical agent noting that it is not interested in certain topics and not wanting to comment on them. Another strategy being evaluated involves refraining from provocative responses while at the same time refraining from avoiding the presence of abusive language.

Additionally, visual appearance can play an important role in guiding expectations and managing such interactions. In a related study (Gulz & Haake, 2010) a female pedagogical agent in the role of coach for a technology domain was given two different embodiments, one more feminine-looking and one more neutral-looking. The more feminine-looking character was more frequently commented upon in

derogative terms, whereas the more neutral-looking was discussed in more positive terms. We will continue to explore what influence manipulations of visual gender can have.

For the early versions of our systems and the visual characters as in Figure 5, the results so far indicate that the amount of agent abuse is considerably smaller and takes milder forms than in the study from Veletsianos et al. (2008). The comparison should, however, be taken with caution, since there are differences not only in the visualization of agents but also in the educational systems used, the period of time for use, age of students as well as the cultural context.

## 6. Future trends and research directions

While this paper has described challenges, design thinking, and possible solutions to common problems when implementing pedagogical agents, it is important to highlight the ways future research can support the extension of this way of thinking.

To the extent that off-task conversation fulfills the purpose of establishing a social relationship with the learner, there is a potential for pedagogical interventions that deserve further attention – such as pedagogical interventions based on identification and role-modeling. To the best of our knowledge, this project represents the very first implementation of off-task interaction in educational software intentionally designed to serve a set of pedagogical interventions.

An important area that needs to be explored further, in relation to the above, and in relation to other issues is *long-term studies*. What can be accomplished when a pedagogical agent based educational system is used for a longer period of time? The need for such research has been pointed out for quite some time and by several researchers (e.g. Dehn & van Mulken, 2000; Gulz, 2004; Bickmore & Picard 2004). With more mature agent-based educational systems, the time has come where such studies can actually be carried out. For example, it is known that a well-designed conversational pedagogical agent during short-term use can positively influence self-efficacy beliefs in students (Baylor, 2009; Kim, Baylor, & Shen, 2007; Baylor & Plant, 2005) but little is known about long term effects. Regarding the role of visual appearance of pedagogical agents on self-efficacy beliefs and other pedagogical measurements, again most studies have dealt with short-time use. The field stands before the exciting task of also examining the role of appearance when a human-agent social relationship persists over time (cf. Baylor, 2009).

An important and much-needed trend in the field is that studies on conversational pedagogical agents have become considerably more fine-grained than they used to be a decade ago. It is no longer discussed whether educational systems are better with or without conversational pedagogical agents. Instead studies are concerned with what kinds of agent can affect what aspects of performance or attitudes in which learners. Another example of studies becoming more fine-grained is how studies of agent gender do not stop at comparing male and female agent characters, but involve different aspects of femininity and masculinity in appearance (Gulz & Haake, 2010).

In addition to research trends and research areas that necessitate our attention, we see a need to rethink the methodological approach we take to pedagogical agent research. Specifically, Design-Based Research (DBR) methodologies allow researchers and practitioners to fully understand pedagogical agent implementations, challenges, solutions, and theories, and we suggest employing such methodologies for future interventions.

Edelson (2002) suggests that three types of theories can be generated from DBR studies. We see our work as informing two of these three theories. Specifically:

- Domain theories: the implementations and iterations described in this paper enhance our understanding of interactions between learners and agents within digital learning environments.
- Design Frameworks: the design, implementation, evaluation, and redesign of the pedagogical agents described herein inform and improve the design guidelines proposed by the EnALI framework (Veletsianos, Doering & Miller, 2009).

In sum, DBR affords researchers with the opportunity to experiment with interventions in authentic environments to explore what happens in the “real world”. Future work in the pedagogical agent domain can fine-tune and enhance situated practice while also enhancing theory on agent-learner interactions if we employ a DBR approach to pedagogical agent research. In line with DBR methodologies, this paper describes our thinking and initial design decisions for the project described herein. We will be revisiting the ideas presented here and will be revising the intervention continuously based on data from the field, feedback from teachers and students, assessment results, and evaluations of the learning experience.

## 7. CONCLUSION

This chapter has provided examples of how one can reason about dealing with the complexity of decisions within one coherent framework (the EnALI guidelines) and still make progress towards a small number of well-defined, educational goals. Unlike traditional, experimental research which provides a “yes” or “no” answer to a given research question, or the rejection or acceptance of a hypothesis, a design-based approach to development maintains the focus on the “how” in an on-going enhancement process as to *what actually works in a virtual learning environment* and the socio-cultural environment in which it is being used. The results we obtain in terms of what manipulations yield a positive or negative effect, for example, might be more or less limited to the implementation context. Yet, of greater benefit is the generalizability and applicability of the lines of reasoning, data collection procedures, and strategies for dealing with enacted interventions at different stages of development, which are likely to inform similar endeavors of enhancing interactions in real-world learning environments.

In our case, we have aimed to demonstrate how the field of conversational pedagogical agents represents a unique combination of theory and research intertwined with practice. This chapter has highlighted the fact that design and research knowledge are important in developing effective, efficient, and engaging pedagogical agents that not only capitalize on technological advancements, but are also sensitive to cognitive, emotional, and social considerations as they relate to educational issues. Taking a design-based approach lends promise to enhancing design practices of conversational agents not as pedagogical tools in isolation, but to improving and understanding the dynamics of the actual learning environment as a whole, with respect to particular measures and treatments as well as to theories and interpretations that lead to usable knowledge.

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## KEY TERMS AND DEFINITIONS

### Web-based education

Education that is enhanced with the use of the World Wide Web.



**Pedagogical agent**

Computer generated characters in a pedagogical role. Examples include virtual instructors, mentors, coaches or learning companions. Such characters appear in numerous educational settings including formal education (e.g., pre-school and university settings) and informal education (e.g., video games).

**Conversational pedagogical agent**

A pedagogical agent that is able to engage in a (textual or spoken) conversation with a learner.

**Social agent**

A pedagogical agent that is able to relate socially with a learner, and engage in social-oriented dialogue as well as task-based dialogue.

**Teachable agent**

A type of pedagogical agent that is taught by learners. Such agents are grounded on the notion that learners learn best when they teach others. In this instance, learners learn by teaching computer-generated characters.

**Embodiment**

The case where a virtual character is presented as a bodied character. Minimal embodiment refers to the agent being represented as a static feature, while advanced embodiment refers to the agent's ability to use his/her body (e.g., engage in gaze, movement, gesture, etc).

**Intelligent Tutoring Systems (ITS)**

Systems that provide learners with instructions and feedback that adapt based on learner characteristics, preferences, and objectives.

**Dialogue system**

A computer system that interacts with a user using spoken or written language, and possibly other modalities, in a connected dialogue consisting of several turns.

**On-task and off-task conversation**

On-task conversation refers to conversation between learners and pedagogical agents that is strictly focused on a lesson's and the processes required to complete the lesson. Off-task conversation is any conversation between learners and agents that is unrelated to the lesson.

**EnALI**

It refers to the Enhancing Agent-Learner Interaction framework proposed by (Veletsianos, Miller, & Doering (2009) to guide pedagogical agent design. The framework consists of practical guidelines for the effective design of pedagogical agents that are in close alignment with design inquiry and practice. These guidelines focus on enhancing agent-learner interaction, agent message, and agent characteristics.

**Design Based research**

Design Based Research (DBR) is defined by Wang and Hannafin (2006, p.6) as, "a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories."