Interactive Animated Pedagogical Agents

Mixing the Best of Human and Computer-Based Tutors

A Masters Thesis submitted to the School of Education at Stanford University in Partial Fulfillment of the Requirements for the Degree of Master of Arts

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Gratitude … is a sickness suffered by dogs.
- Josef Stalin

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Abstract:

In practice, the role of the internet in education is closer to a massive reference library rather than a learning experience. In the long term, the internet may only be seen as it is now by many educators: a possible element in a teaching system, but not a complete teaching system in its own right. Interactive animated pedagogical agents offer the promise of distilling the wealth of web-based information, applications, and communication resources into a learning experience that meets the needs of individual learners. This would be accomplished by combining the web (as a source of instructional content) with developments in embodied conversational computer interfaces and intelligent tutoring systems, thus generating a promising new variant of adaptive learning systems.

This project entails constructing a small website along with an interactive animated pedagogical agent (or “Learning Guide”) that will demonstrate the potential of this line of thinking. Linda, a Learning Guide, will strive to capture all the best qualities of both human and computer-based tutors while teaching content found on the web. The project will focus on 1) the ability of an agent to individualize content for diverse learners 2) the affective components an animated learning agent can introduce to the learning environment and 3) design principles for creating a website to be used with an interactive animated pedagogical agent.
Introduction:

While the people we interact with every day have distinct personalities, volatile emotions, and fascinating quirks, our computers remain the eminently logical boxes they were in the days of vacuum tubes. But people still treat their computers as if they were people. How many times do you beg your computer for mercy, hoping to retrieve some lost data, or curse at it when it gives you an error message? After years of computers forcing humans to think like machines, autonomous animated agents hold promise for a better way: allowing machines to interact like people.

This project discusses a unique sub-class of animated agents known as Interactive Animated Pedagogical Agents (herein referred to as “agents”, “animated agents”, or “pedagogical agents”). They are “Interactive” in that you can speak to them, and they can speak back. “Animated” refers to their physical embodiment...they have faces and bodies, use gestures to communicate, and can move around a computer screen. “Pedagogical” simply implies they are designed to teach, and “Agent” connotes that they are semi-autonomous: they have goals and make their own decisions on what actions to take to achieve their goals...a programmer hasn’t pre-defined every action for them.

What is an Interactive Animated Pedagogical Agent?

In short, Interactive Animated Pedagogical Agents are animated computer characters that are tied into an artificial intelligence (or “AI”) backend. Think “Microsoft Paper Clip,” but a whole lot smarter, more personality, less annoying, and able to teach. Actually, don’t think of the Microsoft Paper Clip. That was a bad suggestion.
The agent is “embodied” - meaning it has a visual representation - and can detect external stimuli such as keyboard input, mouse position, and mouse clicks. The AI backend has a mood and behavior system to simulate human emotions and actions, as well as various components tied to learning.

Interactive Animated Pedagogical Agents can:

- **Adapt** - A pedagogical agent evaluates the learner’s understanding throughout the interaction, just as a human teacher would, and adapts the lesson plan accordingly. Pedagogical agents will not move on to more sophisticated concepts until it is clear that the learner has a good understanding of the basics. If learners continue to have difficulty, the agent can provide additional instruction.

- **Motivate** - Pedagogical agents can prompt students to interact by asking questions, offering encouragement and giving feedback. They present relevant information, offer memorable examples, interpret student responses, and even tell a clever joke or two.

- **Engage** - Pedagogical agents have colorful personalities, interesting life histories, and specific areas of expertise. They can be designed to be the coolest teachers in school.

- **Evolve** - Pedagogical agents can be revised and updated as frequently as necessary to keep learners current in a rapidly accelerating culture. They can search out the best or most current content available on the web to enrich the lessons that someone else has previously designed.
Why use an Interactive Animated Pedagogical Agent?

...all of the computer-based personae that weave through popular culture have one thing in common: they mediate a relationship between the labyrinthine precision of computers and the fuzzy complexity of man. - Brenda Laurel

The power and flexibility of the World Wide Web suggests the possibility of a protean learning environment that tailors itself in both style and content to each individual learner’s needs and capabilities. To achieve this vision, however, educators will need powerful software tools that can distill the educational content available and create learning experiences that suit both learners and teachers.

Interactive Animated Pedagogical Agents offer a low-pressure learning environment that allows users to gain knowledge at their own pace. These agents strive to achieve the delicate balance of the best aspects of a human tutor and the best aspects of a computer-based intelligent tutoring system. For example, like a human, agents can get excited when a learner does well, yet the learner does not need to feel embarrassed in front of an agent if they need to ask the same question over and over again.

Creating lifelike pedagogical agents potentially provides four important educational benefits:

1. A pedagogical agent that appears to care about a learner’s progress may convey to the learner that it and she are “in things together” and may encourage the learner to care more about her own progress.

2. An emotive pedagogical agent that is in some way sensitive to the learner’s progress may intervene when she becomes frustrated and before she begins to lose interest.
3. An emotive pedagogical agent may convey enthusiasm for the subject matter at hand and may foster similar levels of enthusiasm in the learner.

4. A pedagogical agent with a rich and interesting personality may simply make learning more fun. A learner that enjoys interacting with a pedagogical agent may have a more positive perception of the overall learning experience and may consequently opt to spend more time in the learning environment.

In short, lifelike pedagogical agents seem to hold much promise because they could play a central communicative role in learning environments. Through an engaging persona, a lifelike pedagogical agent could simultaneously provide students with contextualized problem-solving advice and create learning experiences that offer high visual appeal.

What is this stuff based on?

There are 6 main areas of research that Animated Pedagogical Agents hail from:

Affective Computing
http://www.media.mit.edu/affect/

Affective Computing focuses on creating personal computational systems endowed with the ability to sense, recognize and understand human emotions, together with the skills to respond in an intelligent, sensitive, and respectful manner toward the user and his/her emotions.
Artificial Intelligence

http://www.acm.org/crossroads/xrds3-1/aied.html

This branch of computer science is concerned with enabling computers to simulate such aspects of human intelligence as speech recognition, deduction, inference, creative response, the ability to learn from experience, and the ability to make inferences given incomplete information. Three highly applicable areas of artificial intelligence research are expert systems, natural language processing, and representation of knowledge.

Gesture and Narrative Language

http://gn.www.media.mit.edu/groups/gn/

This field studies how artifacts such as agents and toys can be designed with psychosocial competencies, based on a deep understanding of human linguistic, cognitive, and social abilities.

Intelligent Tutoring Systems

http://www.acm.org/crossroads/xrds3-1/aied.html

Intelligent tutoring systems are computer-based learning environments. In contrast to traditional educational software, these programs are not static preprogrammed systems; on the contrary, the computer’s decisions about what problem or what information to present next to the learner, and when and how to intervene, are generated, taking into account a set of built-in components, namely:
• Knowledge about the cognitive structures and solution strategies underlying expertise in that particular domain (also known as the “expert model”)

• A model of the student’s knowledge and skills at a given moment in comparison to the expert system, derived from his or her answers and reactions to the previous problems (also know as the “student model”)

• A set of principles about how to control and influence the student’s learning process (the “tutorial module” or “pedagogical module”)

• And knowledge about how to organize the interface with the student (the “communication module”)

Software Agents
http://agents.www.media.mit.edu/groups/agents/

This line of thought investigates computer systems to which one can delegate tasks. Software agents differ from conventional software in that they are long-lived, semi-autonomous, proactive, and adaptive. The aim is to develop techniques and build prototype agent systems that can be tested.

Synthetic Lifelike Characters
http://characters.www.media.mit.edu/groups/characters/

The goal of Synthetic Characters research is to understand how to build interactive characters that come alive in the eyes of the people who interact with them.
Who is active in the field?

Research Labs

**Center for Advanced Research in Technology for Education (CARTE)**

http://www.isi.edu/isd/carte/

CARTE is part of the Information Sciences Institute at the University of Southern California. There are two projects focusing on animated pedagogical agents: The Advanced Distance Education project is developing tools to create adaptive, web-based courseware incorporating artificial intelligence and the Virtual Environments for Training (VET) is a collaboration with Lockheed AI Center and USC Behavioral Technologies Lab developing training systems which integrate virtual reality and intelligent tutoring technologies.

**Intellimedia**


The IntelliMedia Project at North Carolina State University is interested in creating intelligent, lifelike 3D graphical characters to enhance educational software systems.
Private Companies

Artificial Life

http://www.artifical-life.com

Artificial Life develops, markets and supports intelligent robots for the internet.

Extempo Systems

http://extempo.com/

Designs and builds synthetic actors for incorporation into interactive products for entertainment, education, and business. Based on a 15-year research effort formerly conducted by Stanford’s Engineering school.

Microsoft


Microsoft's Microsoft Agent Group. This is an easily programmable animated character with hooks for speech recognition and synthesis. It has no brains per se, but it's a handy package for those of us who have poor graphics skills. The agents are multi-purpose, and Microsoft's intent is that they can be authored for a variety of uses.
The Learning Problem

Users may have little prior knowledge of pedagogical agents and the ideas they bring to the topic may be misconceptions of what the current developments in the field provide. Furthermore, there has been little effort by practitioners in the field to ground pedagogical agents firmly in learning theory. Lastly, these agents are designed for use with web content, yet there are no existing principles for designing a site that will be used by an agent.

Describing the learning problem:

If users have any idea of embodied pedagogical agents, they probably only know about the Microsoft Paper Clip. Even though this agent has some interesting merits, the majority of people find it counter-productive, if not fully annoying. Since there has been very little work done in this field, and educators in general by and large have little, if any, exposure to this new mode of instruction/interaction style, a "show me don't tell" me approach seems warranted. Furthermore, the work that has been done in this field by research labs often does not involve input from an educational perspective. Rather, the research teams are often composed solely of engineers.

The goal is that once users have a positive experience with the agent (while learning about agents) their conception of the utility of this new instructional style will improve. They will see an exhibition of the affective qualities these embodied agents possess, as well as deep parallels to the high quality of one-to-one human tutoring. This project will feature a pedagogical agent prototype named Linda and an artificial intelligence inferencing engine from Extempo Systems.
**Conceptualizing the learning problem:**

The strategy is to utilize the best qualities of both human one-to-one tutoring and computer-based tutoring, while mitigating the shortcomings of both alternatives. This example will use a “contingent tutoring” style (where the user and the agent share control and direction of the curriculum). This would be accomplished by combining the web (as a general source of reference information) with developments in embodied conversational computer interfaces and intelligent tutoring systems, thus generating a promising new variant of adaptive learning systems.
Literature Review

Introduction

The focus of this project is to look into the nexus of interactive animated pedagogical agents and the web environment. In the review of the literature surrounding this topic I have chosen to concentrate on four areas of research. I will begin with a survey of the existing research on intelligent tutoring systems (including animated pedagogical agents), then look into anthropomorphic interfaces, explore empathy in computerized tutors, and end with a look at the broad range of the most applicable topics from research on motivation in regards to computer-based education.

Insights from Intelligent Tutoring Systems Research

In the past thirty years the promise of computers in education has inspired a great deal of development effort toward intelligent tutoring systems, or ITS. Most ITS research is based on two general assumptions about what will provide effective tutorial instruction (VanLehn, 1988). First, the intelligent tutoring model is based on the principle that what a tutor says is critical and it is beneficial to indicate more than merely what is “wrong” or “right.” More specifically, it is believed that by modeling the student’s knowledge and processes it will be possible to explain to the student their misconceptions of the subject matter that have resulted in errors (Anderson, 1988). Second, the majority of ITS research has been aimed at establishing methods to accurately describe a student’s knowledge. The belief here is that tutoring based on fine-grained models of the student will be more effective than tutoring based on more general models or than tutors that only offer algorithmic prescriptions based solely on
detailed task analyses. These two assumptions provide the basis for the design of intelligent tutoring systems.

In designing these systems, it is useful to view them as being composed of five components: the pedagogical module, the domain knowledge, the expert model, the communications module, and the student model (Wolf, 1992).

Pedagogical module provides a model of the teaching process. For example, information about when to review, when to present a new topic, and which topic to present is controlled by the pedagogical module. The student model is used as input to this component, so the pedagogical decisions reflect the differing needs of each student.

The domain knowledge component contains information the tutor is teaching, and is the most important since without it, there would be nothing to teach the student. Mostly facts and procedures, as opposed to concepts or abstract ideas are ingrained in this model.

The expert model is similar to the domain knowledge in that it must contain the information being taught to the learner. However, it is more than just a representation of the data; it is a model of how someone skilled in a particular domain represents the knowledge. By using an expert model, the agent can compare the learner's solution to the expert's solution, pinpointing the places where the learner has difficulties (Wenger, 1987).

The communications module is simply a set of parameters that the system uses to determine how to communicate with the user.

The student model stores information that is specific to each individual learner. At a minimum, such a model tracks how well a student is performing on the material being taught. The tutor needs to know what a student does and doesn’t know
in order to pick the next item to teach. There are many reasons why building accurate student models are difficult. These include the inconsistency of student performance, the evolving state of the student knowledge throughout the instruction, and the limited communication detection techniques available to a computer-based tutor. Even a human tutor can have difficulty in determining student misconceptions even with the extra sensory sources, such as voice effects, hesitations, gestures, and facial expressions (Swanson, 1990).

Often ITS systems have trouble tracing back student errors to deeper underlying misconceptions, particularly when a student’s model is inconsistent with a system’s pre-defined category of bugs. All ITS systems view the student model as a subset of the expert model, with the addition of a collection of misconceptions and missing concepts. A missing concept is something the expert has, but the student does not. A misconception is an item the student has, but the expert does not (VanLehn, 1988). Early ITS systems could only represent missing conceptions, with later efforts attempting to incorporate misconceptions. This latter technique was accomplished by employing a library of pre-defined bugs in the expert model. The resulting student model would consist of the expert model and a list of bugs. Most of the ITS research has been directed at creating more finely grained models of the student based on the assumption that tutoring based on fine models will be more effective than tutoring based on general models. However, many researchers have questioned whether generating a detailed explanation of correct and incorrect answers is the best use of research resources (Swanson, 1990). Granted, a more detailed explanation and diagnosis would provide more information for the student to receive and comprehend passively. However, psychologists and educators have long recognized the benefits
when knowledge is generated, rather than received, by the student (Swanson, 1990, among many others).

An important distinction among tutorial strategies, with both human and computer-based tutors, is the degree of control given to the tutor system and the student. These include a 1) lecture system, 2) a discovery system, and 3) a contingent system (Swanson, 1990). The lecture system carefully monitors the students progress and adapts to their changing needs, however, never relinquishes control to the student. The discovery system allows the student full control over the system, with the system only setting parameters or boundaries on the learning environment. The contingent system shares control with the student, whereby the system can respond to questions, but also pose them. To be effective, the system needs to be able to predict, or at least be prepared for, all possible interactions: both unexpected questions, unexpected answers, and in highly advanced systems, unexpected actions or commands by the user.

**Empathy in Computer-Based Tutors**

Despite this dramatic increase in the sophistication of the computer-based trainers described above, almost all of the effort is focused on cognitive, rather than motivational or social, aspects of tutoring. Lepper and Malone (1987) argue that...cognitive principles alone do not provide an adequate basis for determining what a tutor should do, or how, or when. We assert that *motivational* components of tutoring strategies are as important as cognitive components, and more generally, that truly personalized instruction must be individualized among motivational as well as cognitive dimensions. Hence, we suggest that important benefits may arise from a serious consideration of techniques for creating...
computer tutors that display “empathy,” as well as intelligence, in their interactions with students.

Lepper and Malone back their assertion by citing studies of teachers that indicate that student interest and affect rank high in importance to teachers. Similarly, books on tutoring and reports on school tutoring programs deal extensively with affective issues and place great emphasis on motivational goals and strategies (Rabow, Chin, and Fahimian, 1999). Lepper and Chabay (1985) further suggest “that motivational components of tutoring strategies are indeed important and that many decisions made by human tutors appear to be based as much on the tutor’s sense of the student’s feelings as on the tutor’s assessment of the student’s knowledge and skills.” The pair point out their observations that students of all ages working with educational software support Turkle’s (1984) report that people using computers respond to them as if they are “imbued with personality.”

Lepper and Chabay continue on to lay out some motivational strategies and principles that can be incorporated into computer tutors that they have drawn from human tutors. These include:

- Keep students from becoming discouraged, frustrated, or alienated by reassuring, commiserating, and encouraging
- Encourage high levels of interest and effort by goading, provoking, or reproving the student
- Promote intrinsic motivation by employing a sense of challenge, curiosity, or control. This is done by setting goals, providing hints, incomplete information, pointing out inconsistencies in the student’s
approach, or boosting a sense of control by not intervening at each and every point at which the students seems in danger of making an error

**Motivation and Anthropomorphic Interfaces**

Anyone who tries to influence human behavior has been concerned in one-way or another with the question of why people do the things they do, or in other words, with motivation. A particular area of motivation that animated pedagogical agents are particularly well suited to transmit is that of self-efficacy. According to Bandura (1986) perceptions and feelings of self-efficacy (“I am good at it. I can do it”) are intrinsically motivating. People in general like to do things they feel they are good at. Students are motivated and invest considerable effort when they expect that they can master a task. Bandura offers considerable evidence that individual’s beliefs about their competence and control in relation to a domain of knowledge play a major role in their performance.

At Stanford’s Social Responses to Communication Technologies Research Group Nass, Reeves, et al., formalized the intuition that people apply social rules to many aspects of HCI (for example, Nass, Moon, and Fogg [1995] and Nass, Steuer, and Tauber [1994]). The often-cited studies of this group have been used to counter arguments that the attempt to build social intelligence into computer programs is frivolous. This work supports a counterargument that can roughly be stated as “designing software as a social interface is not something we can avoid because it happens whether we plan for it or not; we have no choice in doing it but only in doing it right.”

The studies have illustrated that even when computers were not given explicitly anthropomorphic interfaces, users tended to see them in this light anyway and showed preferences relative to artificial personalities. Although these studies
were not intended to suggest that the computer programs used were animated agents as such, they did serve to illustrate that the association of a persona with certain types of programs was relatively easy to establish and, in some cases perhaps, hard to avoid.

The most applicable research in this area (for the purposes of this project) is that done on intelligent tutoring systems that utilize anthropomorphic interfaces. The IntelliMedia Initiative at the Multimedia Laboratory of North Carolina State University has an agent, Herman the Bug, which is of particular interest to this discussion. Herman The Bug, an impish buglike creature that teaches children about biology, is the heart of a project that focuses tremendous attention to detail in graphics, gesture logic, sequencing, and theoretical underpinnings.

To this end, a large-scale study about the affective impact of an animated pedagogical agent was conducted in 1997 using Herman. The study revealed the *persona effect*, which is that the presence of a lifelike character in an interactive learning environment—even one that is not expressive—can have a strong positive effect on student’s perception of their learning experience and themselves (Lester, Converse, Kahler, Barlow, Stone, and Bhogal, 1997).

In order to achieve their results, the experimenters (1) exposed a large number of students to agents in controlled learning experiences and (2) obtained students’ assessment of the agents on a number of affective dimensions including helpfulness, clarity, and desirability. They also sought to determine the pedagogical effects of the agents on learning effectiveness. The group developed five clones of the same agent, each of which interacted with 20 students. Each clone was identical to the others in
appearance, but it communicated with different explanatory behaviors. Some were more visually expressive while others were more verbally expressive; some provided high-level, principle-based advice while others provided low-level, task-specific advice; one provided no advice at all.

The results showed conclusively that interaction with the agent during the learning task improved significantly from pre-test to post-test. For my purposes, the most significant finding of the group was the presence of a motivational effect. Evidence was found that because of the engaging nature of the fully expressive agent, there was a significant increase in the positive perceptions of their learning experiences. The researchers believe that lifelike characters create enthusiastic reactions in large part because their believability and human’s innate responses to psycho-social stimuli. Encouragingly, the group is set to release later this summer a separate large-scale study focused solely on this aspect of their research.

The strength of the persona effect was evidenced by its impact with all of the clones. Students’ perception of the agent’s concern for them, the high degree of credibility they ascribed to it, and their perception of its utility and entertainment value all point toward the powerful influence of the persona effect. Even students interacting with the muted clone, whose advisory behaviors were non-existent, perceived the agent in a very positive light. This finding is indicative of a fundamental benefit provided by animated pedagogical agents, perhaps even if they are not optimally designed.
The Features

Based upon my learning problem and the relevant research, I established the following strategies and features list for my adaptive learning system:

- Use the agents ability to model moods (i.e. confident or frustrated) to individualize content.
- Use a conversational interface to customize the same static content for a variety of diverse learners.
- The agent will not only direct the user toward curriculum material, but also try to gain the user's trust and respect by being able to engage in natural conversation about a wide range of topics, like a human tutor could.
- The site will prompt users with clues on how to best interact with the agent.
- The site has a non-linear structure: the character determines the interaction path.
- The agent will try to assess the student's self-confidence and provide encouragement when necessary.
- The agent will attempt to assess the user's prior knowledge on a subject and provide content that is on their level.
- The site will adhere to design principles I have developed to work most effectively with the agent (see Site Design Principles in this document).

Demonstration of Features and Interaction

This section will step through the five major areas of the project with a brief description of each screen.
Area 1: The welcome page

What Happens: The page is very simple, focusing all attention on Linda (see Figure 1). Linda immediately engages the learner in a seemingly “small talk” conversation. In actuality, Linda is starting to build her model of the learner.

Purpose: 1) Establish Linda’s personality 2) Begin simple and natural assessments of who the user is and their learning goals.


Area 2: What is a Learning Guide?

What happens: Prior to coming to this page Linda assesses whether the user is a learner, educator, or partner and tailors the conversation accordingly (see Figure 2 and Figure 3). There is only one page for this piece of content; however, Linda’s dialogue is altered depending upon the background and needs of the user.

Description of Page Content: Pictures of items Linda is referring to: Van Gogh and Kyra.

Purpose: 1) Demonstrates Linda’s adaptability to user needs 2) Shows a simple form of individualized instruction 3) Shows how Linda can make static content have different meanings to different learners 4) Provides basic knowledge about a Learning Guide.

Learning Theory involved: Vygotsky’s theory of “Zone of Proximal Development,” the Persona Effect.

Area 3: Why use a Learning Guide?

What happens: Using knowledge about the goal of the user, Linda will select from three different pages of content. Also, Linda’s discourse is altered depending upon the background and needs of the user. This page will contain several bullet
points on why learning guides are uniquely beneficial modes of instruction (see Figure 4). Linda will solicit the user to nominate which of the items they feel is the “best”, most applicable to their needs, or most applicable to the majority of learners. Linda will then expand upon the selected bullet point in depth, using examples, throwing to a relevant URL (on our site), or quoting some line of research (depending on the user, this research could be on learning effectiveness [for educators] or about ROI [for the corporate training types]).

**Description of Page Content:** One word bullet points of advantages of Interactive Animated Pedagogical Agents that would be most applicable to a particular learner.

**Purpose:** 1) Demonstrates Linda’s adaptability to user needs 2) Shows a simple form of individualized instruction 3) Exhibits Linda’s ability to facilitate co-directed learning - where Linda provides basic structure, while preserving the user’s ability to determine the course of instruction 4) The clickable bullet point exhibits Linda’s ability to sense user activity.

**Learning Theory involved:** Contingent Tutoring, Vygotsky’s theory of “Zone of Proximal Development”.

**Area 4: How to make a Learning Guide?**

**What happens:** At the beginning of this page Linda will need to do a mini-assessment (two questions) to determine the prior knowledge of the learner about computer systems and about their own feelings of whether they could learn to build a Learning Guide (see Figure 5 and Figure 6). Using this information she will decide which of three possible diagrams will appear on the page (see Figure 7). The three diagrams will vary in depicting an increasing complexity of the production process for a learning guide.
If the user expresses low feelings of self-efficacy, Linda will first work to build the user’s confidence that they can learn this material. Then she will walk them step-by-step through the diagram.

If the user expresses high prior knowledge of computers, then Linda will take them directly to the information and play a more background role, explaining just the higher level flow and let the expert user build their own knowledge.

Once she is done showing the user the diagram, Linda will attempt a mini post assessment (see Figure 8). First she will assess self-efficacy by asking whether they think they could follow the steps to build a Learning Guide. If the user answers no, Linda can ask if this because the diagram was confusing or if they would like Linda to explain it another way (perhaps with a flowchart this time). If they answer “yes” they do feel confident they could build a Learning Guide, Linda can ask them if they want to get more involved in the Learning Guide project.

**Purpose:** 1) Demonstrates Linda’s adaptability to user needs 2) Shows a simple form of individualized instruction 3) Exhibits Linda’s ability to boost learner self-efficacy and motivation 4) Displays Linda’s ability to scaffold learners of varying abilities: more guidance for novices and more of a background role for experts 5) Shows Linda’s ability to assess self-efficacy and illustrates how her positive comments may have contributed to the user feeling they can master this domain.

**Learning Theories involved:** Self-efficacy, intrinsic motivation, Persona Effect, Contingent Tutoring, Vygotsky’s theory of “Zone of Proximal Development”.

**Area 5: About Linda**

**What happens:** During the conversation with the user or if Linda brings up a topic that relates to Linda’s persona, Linda will bring up a page that features visual representations of these topics (see Figure 9).
**Purpose:** These pages are designed to support Linda’s persona. These pages are conceptually similar to a human pulling out pictures from their wallet during a conversation.

**Learning Theory involved:** Persona Effect, intrinsic motivation (Lepper & Malone’s “fantasy” element).
User Testing

**Goal:** To evaluate the overall learner experience, especially looking at the affective, motivational, and outlook on learning (engagement/investment, perceived value of learning) elements.

**Methodology:** pre-test assessment of background on agents, 10-15 minutes to interact with Linda, 10-minute conversation about the experience. No quantitative evaluation.

The user testing will take place after the initial version of the site is available. Since the central learning problem concerns the interplay of the agent, the site content, and the user, I felt it important to have the site near completion before conducting testing. I believe, in this case, using anything less than the “real thing” will provide marginal user experience and learner satisfaction data. Ideally, the user tests will not only cover a full range of usability issues, but will also look to confirm that the site achieves the learning objectives and collect some data on the participation of the concepts of education listed below:

- Increasing learners’ feelings of self-efficacy (belief that they can learn/master this material)
- Sustaining learner motivation (level of engagement, use of fantasy element, learning perceived as an enjoyable experience)
- Removal of emotional barriers to learning (closely related to motivation and self-efficacy: fear of asking the same question over and over again and looking stupid in front of another human)
• The Persona Effect (lifelike personae are perceived as being helpful, credible, and entertaining. Plays on the fact that people are good at using the natural and sophisticated ways of interpreting other people)

• Conversational style/interface as a better way to convey information (closely related to Persona Effect)

• Individualized instruction (ties to the adaptive nature of agents; allows for diverse learner styles and levels of prior knowledge. Also, the agent’s ability to tap into a wider range of content on demand, such as web-based databases)

• Just-in-time learning (providing just the knowledge a learner needs right at the moment they need it)

• Meta-cognition (allowing the learner to monitor what they know and don’t know - forces learners to clarify their thought process because they have to write what they are thinking in order to communicate with the agent)

• Explicit representation of pedagogical actions or strategies (connects with meta-cognition in that learners see the structure of the learning path and have information about how big a step they are taking along the way)

**Types of Testing Conducted**

**Usability**

• Check all links

• Navigation evaluation (efficiency of navigational structure)

• Interaction with agent (agent’s ability to know where it is within the site, agent’s ability to correctly parse JavaScript sent keywords)
- Site performance (load times, agent start-up time, low bandwidth performance, low processor performance, low RAM performance)

Character Issues

- Evaluate the robustness of Linda’s personality
- Was Linda’s behavior consistent? Was she believable?
- Identify Linda’s strengths and weaknesses
- Was Linda an effective guide to the pages she showed?
- Did Linda engage user interest?
- Did these webpages work better with Linda as a guide rather than without her?

Learner Outcomes

- Written and graphical content evaluation
- Efficacy of the site with regards to learning objectives
- Evaluation of the user experience
- Evaluation of affective dimensions such as encouragement, utility, credibility, and clarity

Learner Outcomes Testing

Due to the enormous amount of unknown issues surrounding such a new idea as interactive animated pedagogical agents, I believe an informal empirical evaluation will best inform the learner outcomes portion of the project. This evaluation will simply involve having a limited number of diverse users visit the beta version of the site and interact with Linda. The users will visit the site for approximately 20 minutes, and then will engage in a conversation with the evaluator about the experience. A
A small survey will also be utilized to collect user ratings of the experience and efficacy of the site and character.

**User Testing Results (abridged)**

- Five of the six subjects felt there was too little content or the content was too superficial.

- The interaction style got high marks, but took all participants 2 - 3 minutes to settle in and get used to the conversational interface.
  - I wondered how long they would continue interacting if I wasn’t sitting right over their shoulder.

- Site design got high marks for usability.
  - Some confusion on the prompting questions: one user used them more than I would have liked.

- Liked Linda’s persona - felt it was strong and compelling.

- When I asked about self-efficacy, they could not recall a time when Linda had encouraged them.

- Most remarked it did not feel like “learning.” It was more like a conversation or “activity.”

- All felt they could learn from this and that it is quite different than the Microsoft Paper Clip.
  - The paper clip is dumb; Linda is cool: she shops at Dusty and Chloe’s vintage shop!
Site Design Principles

- A designer should strive for the following feedback loop: the site content should drive interaction with the character while the character’s utterances should drive interaction with the site.
  - An exception to the rule: Perhaps these are two separate, and opposing principles. It does raise the interesting question: which is most important, the site or the character? Is one or the other the focus?
- The site content can be sparse. The agent can elaborate on the content with their dialogue.
  - Progressive disclosure of content details through the character allows us to keep those details from cluttering the site pages.
  - Also site content can be visual and dynamic, rather than lots of text. The character can manage dynamic site content to match the conversation, user model, etc.
- Assessment and collection of student activities, feedback, and feelings is vital for the progression of the curriculum. The site content should drive interaction with a character, in particular, should facilitate the agent acquiring information or assessments of the user in a natural conversational manner.
  - The character’s conversation should attempt to drive a voluntary feedback loop.
  - It is important to remember that conversation is not all a character can do. It can navigate, drive dynamic content, participate in games or other interactions, run applications, read user clicks, etc.
• The site design and content should give clues as to what the agent knows and is prepared to speak about. Conversely, the site content should strive to not imply the agent has knowledge it doesn’t have.
  o This doesn’t have to mean the site cannot contain content the agent doesn’t understand. The character can communicate to the user - “I want to show you something. I can’t really talk about it, but I think you might find it interesting.”

• The site design should minimize the amount of scrolling on a page so that the agent can speak about whatever content is on screen and not have to be concerned whether a particular piece of content is on screen.
  o This is an area where dynamic content on a page can be very powerful, with the character driving content to the user based on the interaction, user model, etc.

• With a character that can have an effect on a user’s progression through a site, the site’s navigational scheme needs to be carefully considered.
  o How will the design show site structure? How will the ability for a user to navigate as rapidly and frequently as they like effect the curriculum, the agent’s efficacy, or the agent’s ability to provide a meaningful user experience? Considerations include using nontraditional metaphors or avoiding menus altogether.
Overview of Design Process

I employed something I have termed “Character-centered design”, in deference to Alan Cooper’s coinage of “User-centered design.” The strategy first focused on determining the curriculum and the character’s persona; then design everything from this foundation. The idea was to allow the animated agent to drive the design of the site, dialogue, and to a small degree the methodology of how the curriculum was taught. As personality traits were developed for Linda, webpages were designed to support them and the curriculum was conformed to how Linda would teach it. The site design also followed hints suggested by Linda’s physical embodiment (such as the purple background in the website).

Since the site has a non-linear structure with the site flow being determined by an AI inferencing engine, a standard flowcharting/storyboarding approach was not efficacious. Instead, I devised a system of “bins” of content. These bins defined areas of content with each major area of the curriculum having it’s own bin into which anything relevant to that topic could be placed. Examples include snippets of dialogue for Linda or webpages to be built. The goal of this unorthodox approach was to document all the possible base elements of all possible interactions and help integrate the various pieces of the site into a significant user experience.
Future Work

There are two major areas for future work. The first is the next evolution of this website and character, learning from mistakes and furthering the content and efficacy. Some ideas include:

- Need to further develop a great deal more content in order to provide a valuable user experience
- Experimentation with the emotional elements
- Experimentation with various site design components
- Need to integrate dynamic content into the site design
- Build capability to allow Linda to dynamically generate prompting questions based on the user model
- Better assessment of Linda’s efficacy to achieve learning objectives
- More firmly tie design, features, and Linda’s abilities to learning theory and strategies
- Flesh out a conceptual framework for tutoring

The second area of future work is a departure in the overall direction of this project, while still inspired from the work and results of the present site. This project has encouraged a shift in the direction from building "tutors" to building computerized Learning Companions that facilitates a learner’s own associated affective responses. The aim of this follow-up project is to build a system that facilitates the learner’s own efforts at learning. The goal of the companion is to help keep the learner's exploration going and going well, by occasionally prompting with questions or feedback, and by watching and responding to the affective state of the learner. These affective states
include watching especially for signs of frustration and boredom that may precede quitting, for signs of curiosity or interest that tend to indicate active exploration, and for signs of enjoyment and mastery, which might indicate a successful learning experience.

The Learning Companion is not a tutor that knows all the answers, but a player on the side of the student, there to help him or her learn, and in so doing, learn how to learn better. Initially, the key focus is to help the computer system recognize aspects of the user’s emotion, and on communicating this to the learner in a way that enhances the learner’s understanding of how emotion is facilitating or hindering the learning experience. Ultimately, the Learning Companion would enable the learner to better take charge of the learning process. For example, the computer system could help the learner recognize that frustration and other negative feelings that accompany failure of an idea is a natural part of the learning experience, and helping the user move past this and not get discouraged to where they quit and think they aren’t good at the learner task, or worse, can’t do it at all.
Bibliography


Sample Pages from the Project

1. Figure 1: Opening Page
2. Figure 2: What is a Learning Guide?
3. Figure 3: What is a Learning Guide?
4. Figure 4: Why Use a Learning Guide?
5. Figure 5: How are Learning Guides Made?
6. Figure 6: How are Learning Guides Made?
7. Figure 7: How are Learning Guides Made?
8. Figure 8: How are Learning Guides Made?
9. Figure 9: About Linda
Figure 1: Opening Page

The page is very simple, focusing all attention on Linda. Linda immediately engages the learner in a seemingly “small talk” conversation. In actuality, Linda is starting to build her model of the learner. In this example Linda is attempting to establish the age of the learner through very natural assessment: if the learner has a niece, then Linda knows there is a high probability that the learner is not a child.
Figure 2: What is a Learning Guide?

On this page Linda assesses whether the user is a learner, educator, or partner.
Figure 3: What is a Learning Guide?

Linda uses the data from the previous page to tailor the conversation to the needs of the user. There is only one page for this area of content; however, Linda’s dialogue is altered depending upon the background and needs of the user.
Figure 4: Why Use a Learning Guide?

Using knowledge about the goal of the user, Linda will dynamically select which bullet points appear on this page. Also, Linda’s discourse is altered depending upon the background and needs of the user. This page will contain several bullet points on why learning guides are uniquely beneficial modes of instruction. Linda will solicit the user to nominate which of the items they feel is the most applicable to the majority of learners and then she will expand upon the selected bullet point in depth.
Figure 5: How are Learning Guides Made?

At the beginning of this page Linda will need to do a mini-assessment (two questions; see Figure 6 for the second question) to determine the prior knowledge of the learner about computer systems and about their own feelings of whether they could learn to build a Learning Guide.
Figure 6: How are Learning Guides Made?

Using this information, and the information gleaned from the previous question (see Figure 5) Linda will decide which of three possible diagrams will appear on the page (see Figure 7).
Figure 7: How are Learning Guides Made?

Below we see one of three possible diagrams explaining how a Learning Guide is made. The example below shows the diagram for the most novice user. Linda’s dialogue will also vary greatly depending on the experience and comfort level of the user.
Figure 8: How are Learning Guides Made?

Once Linda is done showing the user the diagram, She will attempt a mini post assessment. First she will assess self-efficacy by asking whether they think they could follow the steps to build a Learning Guide. Depending on the user’s answer, Linda will respond with remediation and encouragement or push them towards more ambitious goals.
**Figure 9: About Linda**

While during the conversation with the user or if Linda brings up a topic that relates to Linda’s persona, Linda will bring up a page that features visual representations of these topics. These pages are conceptually similar to a human pulling out pictures from their wallet during a conversation to augment what they are explaining.