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Performance, perception, and choice of animated pedagogical agent

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PERFORMANCE, PERCEPTION, AND CHOICE OF ANIMATED

PEDAGOGICAL AGENT

by

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A dissertation submitted in partial fulfillment
of the requirements for the

**Doctor of Philosophy Degree in Learning and Technology
Department of Educational Psychology
College of Education**

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Examination Committee Co-Chair

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ABSTRACT

Performance, Perception and Choice of
Animated Pedagogical Agent

by

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This study was designed to investigate learning with animated pedagogical agents (APAs) in the chemistry domain. Of interest was whether learners achieved more when paired with an APA, the learner's perception of the APA, and whether the ability to choose an APA affected learner performance and perception.

An APA (Animated Pedagogical Agent) is a computerized character that is designed to facilitate learning. The ability of the student to choose which APA to study with was integral to this study, so that the effects of student choice on performance and perception of the APA could be investigated. Further, the student's view of the APA in general was analyzed from open-ended comments submitted by the students.

The APAs were carefully constructed according to cognitive load theory (CLT), the cognitive theory of multimedia learning (CTML) and social agency theory. Presentation of the APA, worked examples and self-explanation prompts for weekly chemistry quizzes were built in accordance with these theories. What is surprising is that the students did not react to the APAs as expected.

The students should have performed better when studying with an APA, and should have enjoyed studying with their APA. However, the results of this study did not reveal this.

The interesting results of this study do not lie with differences sought between the groups. The condition, whether no APA, assigned APA or self-selected APA, did not seem to make a significant difference in this study. What made a difference was the APA itself, whether selected or assigned, and the comments of the students.

One possible interpretation may be that there is an initial novelty effect when students study with an APA, and that this benefit is lost over time such as in this multiple measures study. Further, the APA may be viewed as a kind of decoration, since the appearance of the APA led to significant differences in perception of the APA. Finally, the ability to customize the APA may be linked to student perception of the APA.

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PREFACE

This study reflects my interest in how we interpret and interact with technology, especially technology designed to mimic human behavior and to respond to the user. Although technology continues to advance at a tremendous rate, it is hoped that this paper will serve as a basis for future research with animated agents of all kinds.

CHAPTER 1

INTRODUCTION

Personal computers have existed for many years. However, computerized
characters that assist with learning, also known as animated pedagogical agents
(APAs), are a more recent phenomenon. Ever-improving computer hardware and
software has led to this new application of educational technology, and the
design and capabilities of the APA continue to be refined and improved. Formal
research on APAs began in the 1990's (Lester, Converse, Kahler, Barlow, Stone,
& Bhogal, 1997), although the APA created today would have been impractical or
impossible to implement just 10 years ago. Major areas of research regarding
APAs draw from both cognitive and social theories and include how the APA
affects student learning, student perception of the APA as a persona, and the
effect student choice of APA has on these areas.

This study investigated whether learning with an APA raises chemistry
achievement, whether self-selecting an APA raises chemistry achievement, and
whether self-selecting an APA affects student perception of the APA on learner-
agent relationship, human-like, and engaging subscales, collectively referred to
as persona.

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Overview

How to effectively employ an APA in a computerized leaning environment is the subject of much research. Research is conducted to investigate not only if APAs can help students learn, but also to discover the learner's views regarding interaction with the APA. The research results regarding learning with an APA are inconclusive. The APA seems to be useful for helping students learn more deeply and therefore excel at transfer skills, but results for learner retention are typically not significant (Atkinson, 2002). While many APA studies have resulted in questions and conflicting results (Clark & Choi, 2005), studies have consistently shown that students enjoy learning with an APA (Lester et al., 1997; Atkinson, 2002).

In an attempt to maximize learning, the presentation of an APA will often employ approaches such as cognitive load theory (CLT) (Sweller, 1994) and the cognitive theory of multimedia learning (CTML) (Mayer, 2005). Also important to both the design and presentation of the APA is the application of social theories, such as the computers as social actors theory (CASA) and social agency theory. These social theories regarding APA interaction can be applied in addition to multimedia learning theory when designing learning environments. Standard theories of multimedia learning and new social theories based on APA interaction may be required to develop a modern research study, as social agency theory tends to account for the exceptions to CTML such as the absence of a noted split attention effect when an APA is present (Craig, Gholson & Driscoll, 2002). The most effective APA studies have incorporated both of these theoretical

perspectives, while compensating for their limitations (Baylor & Ryu, 2003; Clark & Choi, 2005).

Definition

An APA is, "a computerized character (either human or otherwise), designed to facilitate learning" (Craig, Gholson & Driscoll, 2002, p. 428). Many researchers have modified this definition to fit their studies, and many other definitions exist. One example that conforms to the above definition of an APA is the animated paperclip that appears in Microsoft Office. A selection of various Microsoft Office agents appear in Figure 1.
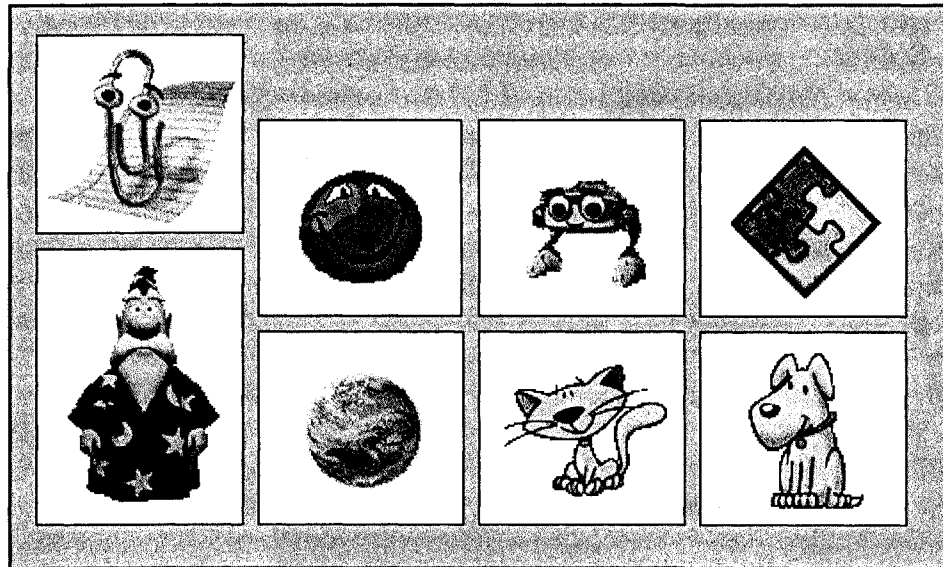
Figure 1. An assortment of the available Microsoft Office agents.

Agents are computerized characters. An APA is a type of agent that is both animated and designed to assist with learning. While an agent may be static and

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not move, an animated pedagogical agent is by definition animated, and movement of some type is implied. In the studies that follow, an APA appears in the computer to mimic a living entity, whether animal, human, or other. Further, while an agent may exist merely to entertain or assist in various ways, the APA is a mechanism to facilitate learning, whether by voice, gesture, gaze, interaction, or other method.

Purpose of this Study

The overall focus of this study was to investigate whether learning with an APA improved chemistry achievement, and whether the option of selecting an APA had an effect on chemistry achievement and on perception of the APA as a persona. To this end, this study addressed three basic questions about learning with animated pedagogical agents. The first question investigated chemistry achievement when using an APA. Would students who studied with an APA learn chemistry better than students who did not study with an APA? The second research question concerned choice of an APA as a learning partner. Would having the ability to select an APA to study with affect chemistry achievement? To answer this question, this study compared chemistry achievement between students who studied with an assigned APA and students who studied with a self-selected APA. The third question also concerned choice, but asked how student choice of APA as a condition affected student perception of the APA as a persona, and also asked how students perceived the APA in general. To answer this third research question, this study compared how students who studied with an assigned APA and students who studied with a self-selected APA differed in

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their perception of the APA as a persona. Perception of the APA as a persona is defined as how the student perceives and relates to the APA on *learner-agent relationship*, *human-like*, and *engaging* subscales on the modified agent persona instrument (API) (Baylor and Ryu, 2003). Further, open-ended student comments were analyzed using a qualitative approach to discern how students perceived the APA in general.

Theoretical Framework

Sparked by conflicting research, debate over whether or not an APA is effective for education continues. A theoretical framework is needed in order to assess the effectiveness of APAs. The APAs rarely appears on the computer screen without other traditional learning materials, so multimedia principles of design are needed, drawn from the cognitive perspective. Motivation and enjoyment are enhanced when learning with an APA and both of these factors can influence learning (Lester et al., 1997; Atkinson, 2002), indicating the need for a social perspective as well.

As it becomes apparent that learners tend to think of APAs more as personas or entities than as multimedia components, social theories regarding learner-agent interaction have been developed more recently. The presence of an APA and the ability to choose an APA as a study partner can affect learning, perception, motivation and enjoyment (Nass, Isbister, Lee 2001; Lester et al., 1997; Atkinson, 2002). Employing social agency theory provides a framework with which to investigate the effect of learner choice on both student performance and student perception of the APA as a persona. This study employed a multiple

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framework of CTML and social agency theory, adapting the principles of CTML that consistently apply to APA research, and incorporating social agency theory to design and guide the interactions between the student and the APA.

Cognitive Theories of Learning

Cognitive learning theories, including multimedia learning theories such as cognitive load theory (CLT) and the cognitive theory of multimedia learning (CTML) serve as the theoretical framework for most APA research. These theories, which have been developed over time and build upon a strong research base, provide guiding principles for developing multimedia presentations. Exceptions to these principles have been noted when CTL and CTML principles are applied to multimedia instructional designs which employ APAs (Atkinson, 2002). Theories of multimedia learning alone cannot account for the complex social interactions that occur when an APA is present, and cannot account for exceptions to CTML such as the apparent lack of the redundancy effect, in which the APA should have distracted the learner from the task. The design of this study employs both CTML for the layout and timing of the learning environment, and social agency theory to design the interaction between the student and the APA.

Social Theories regarding APAs

Social theories based on agent interaction such as social agency theory and computers as Social Actors (CASA), serve as a necessary framework within which to conduct APA research. In these new social theories, learners tend to treat APAs as personas or entities rather than as education materials. As

learners tend to treat APAs as social entities, social theories based on agent interaction may account for some of the notable exceptions to multimedia theory.

The persona effect (Lester, 1997) appears to have been an early recognition that a theoretical framework beyond CTML was needed. This study used APAs. The persona effect implies that motivation and emotion are significantly influenced by the inclusion of an APA. Social interaction exists between the learner and the APA (Dunsworth & Atkinson, 2007). Social agency theory and related theories such as CASA provide the framework to view the agent in the learner-agent relationship as something other than a multimedia component such as a block of text or a picture. The APA in these social agency frameworks is viewed as an entity which the learner reacts to, at least partially, on a social level (Nass, Isbister & Lee, 2001).

Social theories regarding APA interaction influence not only the presentation, but the design of the APA. Learner characteristics such as emotion, motivation, and choice may interact in complex ways with APA design. Elements of APA design include visual appearance, movement, gesture, gaze, voice, and other animations which direct the student, such as a shrug or a nod. These elements play an important role in creating and programming the APA, as they affect how the learner responds to the APA (Gulz & Haake, 2006). For example, studies are beginning to report that the appearance of an APA may influence learner actions. To date, most research has been directed toward improving APA functionality, automation, and animation through programming motion, speech, and gesture rather than detailing the appearance of the APA. It may be necessary to spend

more time and effort in basic APA design so that the look of the APA is appropriately suited to the role of the APA (Gulz & Haake, 2006).

In an effort to avoid the race and gender bias that seems present when a choice of APA is offered, this study led APAs that were carefully designed to appear race and gender neutral (Moreno, Flowerday & Frechette, 2005). For example, depicting specific gender and race can significantly affect learner perception and performance. The few existing studies on choice focused on the learner's preference regarding the gender and race of the APA, despite calls for expanded research on learner choice of APA (Moreno & Flowerday, 2005).

A constructivist approach may also be applicable to APA research. One of the seven goals for the design of constructivist learning environments is to allow the learner to have some control, ownership and voice in the learning process (Honebein, 1996). Allowing the student to select an APA would certainly meet that goal, and should therefore increase the student's enjoyment and cognitive performance as well. The ability of the learner to choose the APA has been shown to affect learner performance (Moreno, 2005). The effect of learner choice was apparent in a recent study depicting an overwhelming preference for using APAs (Moreno & Flowerday, 200).

Research Questions and Hypotheses

This study investigated how learning with an APA could affect the performance of the learner. This study also investigated whether learner choice of an APA as a study partner could affect both the performance of the learner and their perception of the APA as a persona. Learner performance was

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operationally defined as accuracy on weekly chemistry quizzes. Learner perception was operationally defined as how the learner views the APA as a persona or social entity. Performance scores were measured over time through weekly quizzes, while perception scores were collected through a survey and several open-ended questions at the end of the study.

Research Question 1: Do students who study with an APA achieve higher chemistry scores than students who study without an APA?

It was expected that learning with an APA would increase student performance as measured by chemistry achievement. Research has found that transfer skills may be increased when learning with an agent (Atkinson, 2002), and more recent research has found an increase in retention when learning with agents (Dunsworth & Atkinson, 2007). As this study took place over five weeks, the ability to transfer knowledge from week to week as new problems arose should have resulted in higher performance scores in the chemistry domain. Further, social agency theory suggests that students enjoy learning with agents (Nass, Isbister & Lee 2001; Lester et al., 1997; Atkinson, 2002) and experience motivational gains (Astleitner & Wiesner, 2004; Baylor & Ryu, 2003), which should have resulted in an increase in performance.

Research Question 2: Do students who study with a self-selected APA achieve higher chemistry scores than students who study using an assigned APA?

It was expected that having a choice of which APA to study with would increase student performance as measured by chemistry achievement. Choice has been found to affect performance in prior research (Moreno & Flowerday,

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2005). From a Social Agency perspective, having the ability to choose your own APA is similar to having the ability to choose your own instructor. The ability to choose allows the learner to participate in the learning process and to exercise some ownership of that process (Honebein, 1996), which should have resulted in positive motivational gains and therefore performance gains.

Research Question 3: Do students who study with an assigned APA perceive the APA as more of a persona than students who study using a self-selected APA, and how do the students perceive the APA in general?

It was expected that students who self-select an APA would perceive the APA as more of a persona than students who were assigned an APA. Perception of the APA as a persona is defined as how the students perceives and relates to the APA on *learner-agent relationship*, *human-like*, and *engaging* subscales. These expectations were based on social agency theory as well as findings that choice has been shown to affect student performance. Further, allowing for choice should increase learner satisfaction and motivation (Honebein, 1996). It was expected that this satisfaction and motivation would positively affect the social agency relationship between the student and the APA, resulting in a heightened perception of the APA as a persona. In addition, several open-ended comments from students regarding the course were expected to mention the APAs, and these comments were qualitatively analyzed to determine the student's perception of the APA in general.

Overall, it was expected that studying with an APA would increase student performance in chemistry achievement. It was expected that self-selecting an

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APA would increase student performance in chemistry achievement over having an APA assigned. It was expected that perception of the persona of the APA would increase if the student self-selected an APA, and it was expected that students would generally have a favorable view of the APA, in accordance with the review of the literature.

CHAPTER 2

REVIEW OF LITERATURE

Modern research continues regarding how to effectively employ an animated

pedagogical agent in a computerized learning environment. An animated

pedagogical agent (APA) is "a computerized character (either human or

otherwise), designed to facilitate learning" (Craig, Gholson & Driscoll, 2002, p.

428). This study investigated whether learning with an animated pedagogical

agent (APA) improves chemistry achievement, and whether the option of

selecting an APA has an effect on both chemistry achievement and on

perception of the APA as a persona, and how the student perceives the APA in

general. In order to design both the educational environment and the APA for this

study, a review of the literature is required.

The design of this study employed both the cognitive theory of multimedia

learning (CTML) for the layout and timing of the learning environment and social

agency theory to design the interaction between the student and the APA. The

presentation of the APA is designed in accordance with cognitive load theory

(CLT) (Sweller, 1994) and CTML (Mayer, 2005). Also important when designing

the APA is the application of theories of social agency, such as the computers as

social actors theory (CASA) and social agency theory. As the theoretical

framework for this study is drawn from both CTML and social agency theory, it is

necessary to understand the history of both the cognitive theory of multimedia learning and social agency theory that led to the design considerations of this study. Both CLT and CTML were applied in order to maximize the educational potential of the learning environment and the APAs created for this study.

Modern presentations that involve APAs are multimedia, using hardware and software technology capable of presenting sound, motion, animation and video. Because of these expanded presentation capabilities, the complex interactions now possible with an APA may require a revision of older theory, which was previously suited to static presentations.

Equally important to both the design and presentation of an APA is the application of theories of social agency. People tend to treat computers as social entities (Nass, Isbister & Lee 2001). As students tend to treat the APA as a persona rather than a multimedia component, theories of social agency were formed to provide a framework to account for the APA in the learning environment.

Cognitive Theories of Learning

The review of cognitive theories of learning will include will include dual coding theory (Pavio, 1969) and the multimodal memory model (Baddeley, Gathercole & Papagno, 1998), which define how multiple modes of sensory input are processed. Cognitive load theory (Sweller, 1994) introduced the concept that there is a cognitive processing cost for each element that is presented. Integrated theory (Schnotz, 2002) describes how information accessed through one sensory register may be processed as originating from another sensory

register. The cognitive theory of multimedia learning (CTML) has been specifically designed to accommodate multimedia presentations and is the culmination of many of the theories presented here. Because of its multimedia emphasis, CTML is an effective framework to apply when designing an APA presentation.

Working Memory Model

The working memory model has three main components; a visual channel, an audio channel, and a central executive (Baddeley, Gathercole & Papagno, 1998). The visual component can be described as a mental sketchpad for images, using spatial representations for both 2D and 3D images, while the audio component can be described as an audio loop for speech which employs phonological encoding. Because the two differing types of encoding do not communicate directly with one another in the working memory model, a central executive was proposed. This central executive was conceptualized to enable working memory to actively encode and integrate data from both the audio and visual channels.

The working memory model was later amended to theorize an episodic buffer to act something like a filter, which eliminated the central executive (Baddeley & Andrade, 2000). The working memory model applied the concept of limited working memory to the dual channel concept. Modern theory incorporates several key concepts from the working memory model. Cognitive load theory (Sweller, 1994) and CTML (Mayer, 2005) applied the concepts of dual channels and limited working memory to media and multimedia learning environments, which led to several guidelines for presenting media and multimedia applications.

Dual Coding Theory

Multimedia presentations, such as those using APAs, may use both sound and image to communicate. When both visual and verbal channels of information are presented, learning is more effective than when one channel of information alone is presented. Dual coding theory (Pavio, 1969) explains why presenting two channels of information is more effective than one channel alone, and supports multimedia presentations using an APA.

Dual coding theory distinguishes between verbal and visual channels of information. Dual coding theory states that learning through two channels, audio and visual, is more effective than one channel alone and that you have a better chance of remembering information if it is learned using both channels. These two channels are independent in that they originate from two different sources of sensory input. Despite this independence, a synergistic effect where one mode of information reinforces the other in learning and recall has been noted, as using information from dual channels can increase the number of elements that working memory can effectively process (Penney, as cited in Mayer, 2005, p 23). Dual coding theory has been applied to nearly every successive information processing theory.

Much of dual coding theory is derived from research in semantic coding as it relates to words and the meaning of concepts. Learning, including organization and coding, occurs in short term memory. Dual coding theory is a short term memory model of how verbal and visual channels relate to one another and are encoded. In addition to the concept of dual processing, another premise of dual

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coding theory is that humans have limited capacity in working or short term memory. Working memory can hold about five – seven items of information at any one time (Miller, 1956) and without any extra effort to remember these items such as elaboration, all of those items will be lost and unavailable in about 20 seconds (Peterson & Peterson, 1959). Working memory is limited and of slight duration. Much of dual coding theory is applicable today, and has become a core component in multimedia theory.

Due to the limitations of the human mind and learning, specifically limited memory capacity and the temporary nature of short term memory, strategies for how to learn effectively are required in order to learn most effectively. While these theories have detailed how memory works, a theory was needed in order to apply what was learned. Cognitive load theory included principles based on human learning limitations and how to best organize and present learning materials.

<center>Cognitive load theory</center>

As working memory is of limited capacity and short term memory is temporary, it is feasible that information may be lost if not presented in a manner conducive to learning. The concept of cognitive overload in CLT is a standard that remains one of the hallmarks of multimedia theory. If too much information is being presented at once, cognitive overload may occur. Cognitive overload is the presentation of more information than can be addressed by the learner. Although there are exceptions, CLT guidelines are usually effective, allowing good instructional design to minimize cognitive demands. By reducing cognitive

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demands by decreasing the cognitive load to a point that working memory will not be overwhelmed, effective learning can take place.

Cognitive load can be categorized into three different types: extraneous, intrinsic, and germane. Extraneous cognitive load is where information is not presented in the most efficient manner for cognitive processing, or the information is not related to what the subject is intended to learn. CLT views extraneous cognitive load as unnecessary and artificial, something that has been brought about by bad instructional design (Sweller, 1994). An example of extraneous cognitive load might be an animated company logo on each page of an online tutorial. The animation draws attention, uses cognitive effort to process, and does nothing to assist in learning the material. CLT would suggest minimizing the cognitive load required to process all of the design elements.

Intrinsic cognitive load refers to the cognitive load required for an effective design of the educational material, while germane cognitive load can facilitate learning. Intrinsic cognitive involves arranging and presenting each element of the presentation according to the principles of cognitive load theory in order to minimize the amount of working memory required to process the information. An example of intrinsic cognitive load would be placing related text and images next to each other. CLT describes several principles for designing instruction with the goal of minimizing intrinsic cognitive load (Sweller, 1994). Germane cognitive load refers to the cognitive processes and strategies that assist learning. Although germane cognitive load is still cognitive load, germane cognitive load is

designed or presented to assist learning, such as using arrows to point to various locations on a map.

Cognitive load theory presents several principles. Text and images should appear near to each other to avoid the split-attention effect (Sweller, 1994). Learning material should be presented in succession rather than all at once in order to decrease the cognitive load (Van Merriënboer, Kirschner & Kester, 2003). The redundancy effect states that if the same, or redundant, information is accessed through both channels, a decrease in learning performance may result. An example of the redundancy effect would be reading a passage while concurrently listening to identical spoken text. The cognitive load may be further minimized by using example problems that have been worked out (Van Merriënboer et al., 2003). Partially worked out examples could reduce the cognitive load and may result in greater learning than completely worked out examples.

The process of fading means taking what one has learned through worked examples and removing those examples in steps, so that the learner can eventually complete the task without the example framework. When fading occurs and if prompted, the learner applies self-explanation in order to learn the step. Self explanation may be a vital component in learning the steps of a task. (Renkle, Atkinson & Grobe, 2004).

The 4C-ID (Van Merriënboer, Kirschner & Kester, 2003) stands for the four components of a detailed learning model consistent with CLT. This model is task oriented, and suited toward multimedia training instruction. 4C-ID describes

optimal conditions where learning can take place and consists of four

components as defined:

1. Learning tasks: Worked out examples, or partially worked out examples,

result in deeper learning. This builds upon the foundations of CLT.

2. Supportive information: Knowing something about the task and the best

way to approach the various problems in the domain can assist learning. This

stresses the importance of prior knowledge.

3. Procedural information: The steps required to complete the task should be

defined. Feedback should be provided to correct mistakes.

4. Part-task practice: Practice is critical to developing automaticity, allowing

limited cognitive resources to be applied elsewhere.

The 4C-ID model suggests that an effective way to learn a task is to use

scaffolding and just-in-time information in order to partially reduce cognitive

demands. This approach is suited toward multimedia learning, as instant

feedback is easily provided in a variety of forms. Scaffolding and just-in-time

learning can be provided by an online peer, a trainer, an APA, or even a pop-up

window. In this study, the APA presents the just-in-time information in the form of

an appropriate worked example.

The 4C-ID model supports learning simple elements which are broken down

from the more complex elements that comprise the task rather than trying to

learn the whole task at once. After automaticity is attained and the basic

elements of information are chunked together, more and more complex elements

and sequences can be learned without cognitive overload. Training involves building from the parts toward the whole task.

The 4C-ID model is used to design instruction, and adheres to cognitive load theory. Automation reduces cognitive load and leaves room for new items of information in working memory. Learning in small steps to build up to the whole task takes information in sequence and is unlikely to result in cognitive overload. Just-in-time learning and scaffolding techniques assist in understanding, which further reduces cognitive load.

Cognitive load theory does not account for learner characteristics or individual differences, which may hold exceptions to these principles. Learner characteristics may play an important role in exceptions to the redundancy effect. For example, under certain conditions redundancy may facilitate learning. Kindergarteners learning the alphabet may need to read each letter as it appears and at the same time listen to the name of the letter being spoken. Sweller (1994) did note that if the information is too easy, the redundancy effect may occur. There may be age and skill level differences within the classroom that influence whether or not the negative impact of the redundancy effect will take place. The realization that some students can carry less of a cognitive load than others and may not be able to develop advanced schema, or the mental network necessary to store information effectively, should be considered when designing instructional materials.

There are instances where cognitive load theory does not apply. For example, a study about children's memory and interactive media found a curious result

regarding hot spots, which are clickable points that briefly diverge to other story pages or interactions (Ricci & Beal, 2002). The subject matter of these hot spots was not germane to the story. Cognitive load theory would predict that these hot spots would carry an unnecessary intrinsic load, and should interfere with learning by distracting the learner from the germane load of the storyline itself. However, no matter how many hot spots were clicked or how many times the learners clicked on them, the study found no significant difference in story recall between the hot spot group and the control group. Clicking many times on different hot spots should have resulted in cognitive overload and resulted in less efficient learning, but this did not occur.

In this interactive storybook study, cognitive load theory could not explain these findings. Perhaps the age of the children was a factor, or perhaps there is something intrinsically cohesive about following a storyline, or perhaps the hot spots added motivation to balance out the cognitive load demands. Although it is difficult to know without further research, this study remains a prime example of where some aspects of cognitive load theory may not apply.

Another exception to CLT was noted where learners with low prior knowledge do not engage in mental simulations in certain situations when presented with pictures, while learners with high ability and high prior knowledge can use the pictures to construct mental models. These results may be due to the cognitive load of the pictures resulting in cognitive overload in learners with low prior knowledge (Westelinck, Valcke, de Craene & Kirschner, 2005). Another exception is the expertise reversal effect, where certain educational designs may

assist learning for low level learners but hinder learning for high level learners (Kalyua, Ayres, Chandler & Sweller, 2003). One example of this involves studying worked examples as opposed to traditionally working out the problem (van Merrionboer et al., 2005). Low level learners do quite well, high level learners do not. Note that this opposes the initial 4C-ID model, which was adapted to fit this new information. In controlled, programmed instruction, the 4C-ID model seems very appropriate.

By stressing the awareness of cognitive load, the application of CLT guidelines to instructional material can reduce cognitive demands and increase learning. CLT has become an important theory, and is one of the cornerstone theories used in the formulation of the cognitive theory of multimedia learning (CTML).

Cognitive theory of multimedia learning

The basic tenants of CLT are that there are dual channels, that processing capacity is limited, and that learning is active. Building upon these CLT concepts, CTML has been drawn from many existing theories (Mayer, 2005). Cognitive load theory and dual processing theory are two of the core components of CTML. However, CTML specifically applies these tenants to multimedia, and a multimedia environment is necessary when an APA is present.

Sounds and images are organized and linked in working memory, and integrated with prior knowledge from long term memory schema. Integrated theory (Schnotz & Bannert, 2003) states that certain sounds may process as images when one hears them, as the neigh of a horse will bring forth a mental

image of a horse. The cognitive theory of multimedia learning does not allow for this information to cross sensory registers. Rather, associations and schema from long term memory bring these sounds and pictures together in working memory, to associate and store the new or modified schema in long term memory. As with CLT, prior knowledge is important. The more you know, the easier it is to learn.

In a landmark paper, nine ways were proposed to reduce cognitive load related to multimedia learning. The modality effect suggests that voice narration is better for learning than reading text, whether presented sequentially or at the same time. However, to eliminate redundancy, written text is not presented at the same time as the identical narration. For the design of this study, the voice of the APA will be presented first, followed by the identical text in order to apply the modality effect and avoid redundancy (Mayer & Moreno, 2003).

The segmentation effect states that allowing the learner to view a portion of a presentation at a time is more effective for learning than seeing the entire presentation without breaks. Segmentation allows for more complex concepts to be built, integrating the smaller elements into the more advanced schema. As we can hold only a small number of units in working memory at a time, the resulting piece of information will only count as one unit as that information becomes well integrated with the schema. This study will apply the segmentation effect by presenting individual examples one at a time, at the learner's own pace.

The pre-training effect states that learning is more effective if the learner knows information about the subject beforehand. In this study, APAs will be

available to the students during the quiz, after the weekly presentation of chemistry materials in class.

To reduce extraneous material, both Sweller (1994), and Mayer & Moreno (2003) have these suggestions:

Weeding is the process of removing extraneous material that does not contribute to learning.

Signaling is used to accent where the learner must pay attention, such as using arrows, a map or highlighted text.

Words and graphics should be located in close proximity.

Related narration and animation should be synchronized and presented at the same time. In this study, gestures from the APA serve as signaling, the APA and the narration are synchronized, and extraneous material is not presented.

Not all CTML principles apply when APAs are present. For example, the split attention effect of CTML states that an increase in cognitive load brought about by the inclusion of another item, in this case an APA, will effectively reduce learning. Despite this prediction by CTML, no split attention effect was found when learning with an APA (Craig, Gholson & Driscoll, 2002). This conflicts with the CTML prediction that the presence of the APA would detract from learning. The split attention effect of CTML does not seem to apply when APAs are present.

Design effects are stronger for low knowledge learners than for high knowledge learners, so lessons should be individualized. Design effects are also stronger for high spatial learners than for low spatial learners. With this concept,

CTML acknowledges the concept of individuality where many other theories do not. However, CTML does not attempt to address motivation, emotion, or social issues. CTML also suffers from limited modality. Audio and visual modes are included, but no other modes, such as sound images as integrated theory would later introduce. As multimedia begins to make use of the various modalities, cognitive multimedia theory may need to be refined. For example, the split attention effect of CTML states that an increase in cognitive load brought about by the inclusion of another item, in this case an APA, will effectively reduce learning. Despite this prediction by CTML, no split attention effect was found when learning with an APA (Craig, Gholson & Driscoll, 2002). This conflicts with the CTML prediction that the presence of the APA would detract from learning. The split attention effect of CTML does not seem to apply when APAs are present.

Other modalities such as smell and touch are beginning to emerge in media and multimedia as technology makes these enhancements possible (Reed, 2006). CTML has no framework to cover these sensory modalities, even though the processing of this information is part of our basic cognitive architecture. The sense of smell has long been recognized to aid in memory recall, and even imagining a smell can have neuro-chemical reaction similar to experiencing the actual odor (Levy, Henkin, Lin, Hutter & Schellinger, 1999). If smell can assist in memory recall, then this may be applicable to education. Until recently, smell reproductions for the computer were not practical, and this area is still in its

infancy. However, prototypes are being developed, and smell may someday become a component of the multimedia experience.

Touch is another modality that CTML does not incorporate. Haptic devices that allow the user to experience pressure in the form of feedback from computer peripheral devices are now being actively employed in media and multimedia environments. For example, one use of haptics and a virtual reality environment is in the rehabilitation of stroke patients (McLaughlin, Rizzo, Jung, Peng, Yeh & Zhu, 2005). The authors claim two main benefits from using haptics and virtual reality (VR). One is the immediate feedback that the computer can provide when using haptics, which is beneficial to the patient as well as a method of generating and recording data on the patient's performance. The second benefit is the high motivation level obtained by patients due to the game based nature of the rehabilitation exercises programmed into the VR environment. The first benefit is something that computers have been known for since the days of computer aided instruction (CAI), and that is immediate feedback. The second benefit appeals to motivation, which is beyond CTML and needs to be addressed.

The cognitive theory of multimedia learning is a dominant theory of multimedia today, although revisions to the theory may be needed. Building upon CTML, integrated theory tends to refine the presentation of words and text. However, integrated theory takes exception to the CTML premise that voice is superior to text. Integrated theory proposes that conditions exist where text is superior to voice for learning, such as when the information is complex.

Integrated Theory

Integrated theory is the integrative model of text and picture comprehension (Schnotz & Bannert, 2003). This model uses a multimodal approach, where all modes of sensory input may be processed. The primary channels remain audio and visual. The cognitive architecture remains consistent with sensory registry, working memory, and long term memory. The verbal and pictorial channels are processed in the cognitive level of working memory. Channel information is input at the sensory level, before entering working memory.

Incoming information from any channel is initially processed in the sensory register according to the raw type it contains. For example, words that are spoken and any and all other sounds are perceived by the auditory register. Anything visual, such as written words or a picture will go to the visual sensory register. This information is then processed in working memory.

Integrated Theory divides working memory into two different components, the auditory working memory and the visual working memory (Schnotz & Bannert, 2003). Processing takes place in each of these components in the form of filtering. Auditory information is sent along either the verbal or pictorial channel. Spoken word will continue along the verbal channel. However, what Integrated theory refers to as *sound images*, like hearing the hooting of an owl, will be recognized as an image of the sound, and will move to the pictorial channel in visual working memory. Similarly, visual working memory sends information along either the pictorial or visual channel. An image will continue along the

pictorial channel, but written text will be recognized as auditory information and will move to the verbal channel in auditory working memory.

To summarize, working memory has both audio and visual channels that filter information from our sensory registers. Spoken words and text that is read will move along the verbal channel where language processing begins to take place. Sounds that evoke pictures, like the sound of a fire alarm, move images that we see in our mind along the pictorial channel. Finally, information from long term memory is called into working memory, where mental models and propositional representations work together to encode and make sense of the information.

Integrated theory and CTML are similar in many respects. Although integrated theory uses more modes of information, visual information is not necessarily obtained only from the visual channel, but can be obtained through other modes such as the audio channel. Integrated theory tends to support suggestions and recommendations from CTML, although there are further recommendations for learning and even a contradiction to CTML.

Building upon CTML are three principles from integrated theory: A: The picture – text sequencing principle states that if text and pictures are present at the same time, then the picture should be presented before the text. B: The structure – mapping principle holds that if different pictures can represent the same task but in different ways, then use the picture that is most appropriate for working on future tasks, and C: According to the general redundancy principle, if the learner will have the cognitive ability and the prior knowledge to come up with a mental model using either text or a picture, then use either text or a picture.

Integrated theory holds that adding pictures to text does not always result in greater learning, and may even complicate the construction of a mental model. A study of learning in the domain of meteorology found that information gained from pictures that are realistic can be valuable to the learner, but that pictures that are not realistic and do not make spatial-temporal sense are not very valuable to the learner (Lowe, 2003). If the learner cannot make sense of the image, then learning may be impeded.

Integrated theory does differ with CTML in the control of processing principle. This principle states it is better to use written text with an image if the text is complex and hard to understand and if there are no time constraints. CTML holds that spoken text is superior to written text at all times. The implication in integrated theory is that the learner can review written text for understanding, while spoken text is gone once it is stated. This study will allow the text to remain as long as the learner wishes.

Integrative Theory adds sensory modes beyond CTML, with principles designed to overcome certain limitations inherent in CTML . However, neither CTML nor integrated theory is a complete solution as exceptions to these theories occur, especially when APAs are involved. Although CTML and integrated theory cover the presentation mechanics of learning, social theories regarding interaction between the learner and the APA also exist.

Social Theories and APA Performance

Social theory regarding the APA developed to accommodate the finding that motivation and enjoyment increased when learning with an APA (Lester et. al.,

1997). The Persona effect and social agency theory are addressed first in this section. Social issues regarding the APA include speech, motivation, emotion, and appearance, have also been addressed.

The persona effect is the concept that the presence of the APA can directly affect the learner's view of the educational experience. The persona effect implies that the learner views the APA as having certain personality characteristics, and the persona effect is noted when the APA can influence the learner's view on learning (Lester et. al., 1997).

Social agency theory states that interacting with an APA brings about the learner's social views and expectations of that interaction (Dunsworth & Atkinson, 2007). The learner views the APA as more of an entity rather than a component of the program (Nass & Moon, 2000). Suggestions to make the APA appear more believable support both the persona effect and social agency theory (Lester, Voerman, Towns, & Callaway, 1999; Nass, Isbister & Lee, 2001).

Other APA issues may be addressed through the persona effect and social agency theory as well. The effect of speech, based on guidelines suggested by CTML, appears to be influenced by the presence of the APA (Atkinson, 2002). The APA influences the learner's emotion, motivation and emotion (Moreno, Mayer, Spires & Lester, 2001). The recent question regarding choice of APA to study with has been shown to affect learning (Moreno, Flowerday & Frechette, 2005). Finally, several design considerations of the APA are reviewed.

Persona Effect and Learning

The learner views the APA as having certain personality characteristics. This is the persona effect, "where well-designed lifelike personae interacting with students using learning environments are perceived as being very helpful, credible, and entertaining" (Lester, et al., 1997, p. 360). A persona effect is in effect where the presence of the APA can positively affect the learner's view of the educational experience. Support for the persona effect can be seen in the perception of the APA by the learner, as learners rate APAs as credible, helpful, and entertaining (Lester et al., 1997). While it is generally accepted that there is a persona effect for learners when APAs are used (Atkinson, 2002; Moundridou & Virvou, 2002; Lester et al., 1997), there also exist studies that reveal no persona effect when learning with an APA (Craig, Gholson & Driscoll, 2002).

Another study in which no persona effect or social influence for the APA was noted used a set of APAs collectively named PPPersona in the experimental condition and no APA in the control condition (Andre, 1999). Opposite findings exist in a study resulting in increased motivation and the ability to transfer knowledge to other areas which were attributed to the persona effect of the APA, although no effect was found for retention when learning with an APA (Atkinson, 2002).

A study using two separate APA conditions led to the statement, "Overall, it is inconclusive as to whether agent image and animation are required to create a viable pedagogical agent persona" (Baylor & Ryu, 2003, p. 373). The control group used no APA, the second group used a static image of a Microsoft wizard

agent as the APA, and the third group used an animated image of the Microsoft wizard APA. The subjects consisted of 75 pre-service teachers, who were required to participate as part of the course. Results obtained from questionnaires investigated the effect of static or animated pedagogical agent images on whether the APA seemed engaging, instructor like, credible, or person-like. Variation present in these scores tends to support the persona effect. However, the results of this study have been inconclusive as there was no significant effect for learning with an APA.

Significant results were found for motivation when learning with an APA in the physics domain where the APA was a talking face. Although no significant results were found for short term recall, two motivational advantages were revealed. First, the learners significantly enjoyed working with the APA more than the text only control group. Second, the learners in the APA condition rated the questions as easier to solve than the learners in the text only control group (Moundridou & Virvou, 2002). Findings regarding the motivational advantages of learning with an APA are fairly common, and these findings tend to support the persona effect.

Even within the same study, conflicting results are sometimes visible, such as in the study of APA and voice (Atkinson, 2002). In the second part of this experiment in the math domain, learners in the APA plus voice condition performed significantly better on both near and far transfer than students in the voice only or text only domain. Further, a persona effect was found to be present, as students enjoyed learning with the APA according to the survey results. However, no significant effect for persona was noted for the inclusion of the APA

in parts four and five of the experiment. The author suggests that a social agency metaphor is already in effect as the learner interacts with the computer, and that trying to make this social agency more coherent by adding a visual image may not lead to better results.

Conflicting results continue today, as shown in modern studies. A review of all of the available literature on image effect for APAs came to the conclusion that adding an APA will have no significant effect on the learner (Moreno, 2005). Contrary evidence was found 2 years later in the science domain, which found that learning with an APA significantly enhances learning (Dunsworth & Atkinson, 2007). Apparently, further research with APAs is needed to assess their impact on the learner.

Social Agency Theory and Animation

Many case studies show that APAs can help students learn more deeply, so that knowledge can transfer to new situations (Atkinson, 2002; Moreno, Mayer, Spires, & Lester, 2001; Atkinson, Mayer & Merrill, 2005). Additionally, students seem to enjoy learning with APAs. Social agency theory holds that interacting with the APA brings about the learner's social views and expectations. Social agency theory describes the learner as interacting with another person, to some extent, when they are interacting with an APA (Dunsworth & Atkinson, 2007). How much the students like the APA may influence how hard the students try to understand the material. Therefore, learning with an APA should help the student obtain a deeper understanding of the subject matter as if they were learning with a real teacher.

Animation may help the APA appear more believable, a quality that static images may lack (Lester et al., 1999). Accordingly, static APAs should be much less effective than an animated pedagogical agent. Findings support this concept, as a static image of an APA had no effect on motivation, whereas positive gain in motivation occurred when learning with an animated APA (Baylor & Ryu, 2003). Animation, such as gaze and gesture, was also seen as the most important quality for an APA to be perceived as engaging, according to a survey from the same study. The animated APA was also seen as more instructor-like when compared to the static image condition. Therefore, APAs should look and act as lifelike as possible, even if that applies to non-human APA such as Herman the Bug (Moreno, Mayer, Spires & Lester, 2001), Cosmo the Robot (Lester et al., 1999), or any other creation designed to stimulate the social agency.

Several theories of social agency have developed. Following the computers as social actors (CASA) theory, the authors state, "one can take both theories and methods from social psychology and directly apply them to human-technology interaction" (Nass, Isbister & Lee 2001, p.6). In CASA, APAs are referred to as conversational agents. Research found that people tend to treat computers as we would treat humans, which includes applying gender and ethnicity, using cultural norms such as politeness, and exhibiting reciprocity to the computer for doing something for us. However, when asked to discuss these issues, people do notice this irrationality. Nevertheless, people apply social rules when interacting with APAs, even though they may deny that they do so (Nass & Moon, 2000). Regardless, people regularly apply human traits to computers.

Studies show that APAs are anthropomorphized as well, and we interact with the APA according to our social framework (Nass & Moon, 2000; Nass, Isbister & Lee, 2001).

As part of our social framework, speech would seem a natural method of information delivery for the APA. However, there are certain guidelines from CTML that will be followed as well for this study. Fortunately, both CTML and social agency theory agree overall that speech is a valuable and preferred method of information delivery, although this can vary according to the complexity of the content and the level of the learner.

<div align="center">Speech</div>

A main question regarding how to present an APA is whether to present visual text or to have the APAs speak the words audibly. In general, it has been found that using spoken words is more effective than presenting text, which supports the cognitive theory of multimedia learning (Moreno, 2005). However, exceptions to these guides certainly exist, such as the following study in which text was shown to be more effective for learning than spoken word in the pilot study.

A study asked whether APAs could assist students with worked out examples in the math domain (Atkinson, 2002). The pilot study showed that presented text was statistically more effective for student learning than listening to the spoken voice of the APA, with or without the visual image of the APA present. This contradicts a basic principle of CTML. However, Atkinson theorized that his pilot study was confounded by presenting a computer generated voice and not a real,

human voice. Regardless, the results do go against the cognitive modality premise that voice is superior to text for learning.

In another experiment in Atkinson's study he replaced the computer generated voice with recorded human speech (Atkinson, 2002). The three conditions were APA with voice, voice only and text only. The APA with voice condition was shown to be significantly more effective than both the voice only and the text only condition when learners were tested on transfer tasks. Also, learning with an APA may assist with the deep learning required for transfer tasks (Atkinson, 2002). The generally accepted view, therefore, is that APAs should be able to speak. Their speech should be natural, and they should speak to the learner in a personalized style rather than a monologue (Moreno, 2005).

The principles of redundancy and the superiority of voice over text seem to apply to APAs, supporting the cognitive theory of multimedia learning. The presence of the APA seems to make no difference in this regard (Atkinson, 2002). A recent study in the science domain developed in accordance with social agency theory found that APAs with voice enhanced learning (Dunsworth & Atkinson, 2007). Therefore, following both CTML principles and social agency theory, the APA should speak to the learner when applicable.

Motion and Emotion

The APA should be created to be as realistic and human as possible (Lester, Voorman, Towns & Callaway 1999). Lester's APA, Cosmo the robot, was as high in what Lester et. al. termed deictic believability as possible. Cosmo is fully

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animated, created with realistic motions and gestures in an effort to enhance learning.

The study described previously used a Microsoft Agent that looks like a parrot with green feathers and a yellow bill (Atkinson, 2002). Other than the pilot test, Peedy spoke with a human voice, and gestured with wing and beak, eye movement, head movement and gaze. Gestures such as these may be required social cues for effective APAs.

The APA can be used to direct the learner's attention by using movement, gestures, or eye movements (Atkinson, 2002; Clark & Choi, 2005). Nonverbal feedback is also suggested, and this may take many forms such as head nodding, jumping up and down, shaking one's head, or looking confused. In accordance with social theory, exhibiting motion, gestures and expression may influence how the learner perceives the APA's emotions. A wide range of nonverbal feedback may be effective (Burleson & Pickard, 2004).

Using a number of nonverbal feedback techniques, APAs can exhibit varying forms of approval or disapproval. APAs can also exhibit affective qualities and simulate empathy for the learner (Hone, 2005). A written dialogue designed to reduce frustration was presented to both the APA and control condition. No APA was present in the control group. The frustration device was a game programmed with random behavior such as variable ball speed. Self reports of frustration levels showed a significant decrease for the APA condition over the control condition.

A second experiment in the same study attempted to find a difference between realistic and cartoon-like APAs when testing for frustration reduction. No significant difference was found between the realistic and the cartoon-like APAs. This tends to suggest that cartoon APAs can be just as effective as realistic, photographic quality APAs. Suggestions by the authors include using emotive and empathic APAs tutors that could sense a loss of interest or mounting frustration on behalf of the learner.

A different use for APAs is to cast them in the role of the peer. According to social agency theory, APAs should be able to serve as peers in this context. In a study of APAs as learning companions, or PALS, the effects of low level competency or high level competency PALS were compared (Yanghee & Baylor, 2006). Low level competency was defined where the PAL knew a few facts but not much about the subject and seemed relatively unsure, while high level competency was defined where the PAL knew much more about the subject and sounded more confident. A second independent variable was whether the PAL was proactive and gave suggestions and advice, or if the PAL was more responsive and waited for prompting. Self efficacy and attitudes of the learner were measured. The results showed significantly more learning in the high competency condition. However, students in the low competency condition exhibited significantly higher self efficacy about the task. The learners tended to feel more confident when their PAL was less skilled, and yet they performed less well than the learners in the high competency condition. Finally, learners had a higher regard for high competency PALs than low competency PALs. These

studies begin to show the influence that APAs can have on learners, not only

their performance, but on affective issues as well.

<p style="text-align:center">Choice</p>

Research questionnaires revealed that students like to study with APAs

(Atkinson, 2002; Nass, Isbister & Lee, 2001). In fact, if given a choice, they prefer

to study with an APA. A suggestion for future research was to give the learner

the option to choose their own APA (Baylor & Ryu, 2003). As students might

have a choice of which APA to study with, the impact of choice on performance

needs to be assessed.

In one of the few studies on choice, groups were organized by choice of APA

or assigned APA (Moreno & Flowerday, 2005). Several choices of APA were

available, five male and five female lifelike APAs of differing races. Moreno was

looking for learner preferences regarding the APA's gender and race, as well as

the effect of choice on performance.

Each subject was given the choice of whether or not to study with an APA,

which determined their assignment to the control group or the APA group. In this

study, each subject chose to study with an APA, which resulted in a zero subject

control group. This overwhelming preference for learning with APAs supports

both the persona effect and social agency theory.

The 10 available APAs were crafted to resemble a specific gender and a

specific race. Results showed that Hispanic and African American learners were

significantly more likely than white learners to choose the same race APA.

Learners with the same race APA performed significantly lower on retention,

<p style="text-align:center">47</p>

transfer, and program satisfaction ratings than learners who chose APAs of different races.

Moreno (2003) theorized that these results were due to the interference principle from cognitive load theory which states that some other stimulus is present, vying for the learner's attention. The result would be cognitive overload. As social as interactions with APAs are proving to be, this explanation seems simplistic. The cognitive theory of multimedia learning alone may be insufficient to explain these results. In this case, the application of social agency theory seems more appropriate.

Choice has been shown to be an important factor in APA research. Moreno comments on choice, stating its beneficial effects on both learning and motivation (Moreno, 2005). Suggestions for future research include allowing the learners to design or choose an APA that is appealing to them. This leads to an emphasis on the design of the APA.

<div align="center">APA Design</div>

Much research has been done regarding the voice of the APA, as well as the movements, gestures, and animations of the APA. But other than advice to make APA as believable as possible (Lester et. al, 1997), very little research has been devoted to the appearance of the APA (Gulz & Haake, 2006).

The appearance of the APA does influence the learner's cognitive assessments. In researching embodied conversational APAs, one set of guidelines have been developed for working with APAs based on that study's defined concept of beauty (Lee, Isbister & Nass, 2000). The first guideline for

beauty is accuracy. The appearance of the APA should convey what you intend to convey. The visual design and appeal of the APA are important. This includes functionality such as the scripting necessary to give the APA the appropriate responses, and animation of movement and guiding gestures. Second, the work should be viewed by peers as accurate and of interest. Third, the APA should meet the needs of the users of the technology, so that the learner is actually learning with the APA. Unfortunately, little has been done to standardize these guidelines. Little research has been done on aspects of the appearance of animated agents, even among researchers who acknowledge its importance (Gulz & Haake, 2006).

Obtaining this concept of beauty is not easy when creating realistic APAs designed to convey meaning. Creating a simulation of the human face is difficult, especially when that face must be animated. Predicting the response to the human APA is also difficult. "The great complexity and psychological depth of the human response to faces causes difficulty in predicting the response to a given animated face model" (Gratch, Rickel, André, Cassell, Petajan & Badler, 2002, p.7). Therefore, we cannot fully understand a learner's reaction to an APA until we can define the look of the APA. Using neutral, non-human APAs may be an effective method to eliminate this complication.

A recent study argued that motion, gestures, and facial expressions are almost never tied to the underlying appearance of the APA (Gulz & Haake, 2006). Gestures, speech, and facial expressions should be carefully timed and synchronized. In an APA, neutral expressions without fluctuation do not appear

natural. For example, when the arms move in a real person, the torso will reflect this motion and move slightly also. This realism should be reflected in the APA. Maintaining expressions such as smiling during a neutral gesture do not look natural, so achieving realism requires careful attention when creating the animations.

If computers as social actors and social agency theory apply to APAs, learner stereotypes and judgments may be applied to the APA based on the appearance of the APA. Social psychology includes the halo effect, where people viewed as good looking are rated as having more positive traits than others. These traits include being perceived as independent, social, capable and interesting. Those who are viewed as not good looking are perceived in almost the opposite fashion, and are seen as untrustworthy, not as socially competent, not as cooperative, and not as smart. With glasses on, a person may be viewed as intellectually competent and intelligent, but also less socially competent and somewhat weaker (Gulz & Haake, 2006). According to computers as social actors and social agency theory this bias may pertain to APAs as well.

Aesthetics can influence how opinions are formed. The visual aesthetics of an object can shape a person's perception of how to interact with that object. The look and animations should be carefully considered when deciding how to design and build the APA, both for believability and how the learners will respond to the APA (Gulz & Haake, 2006). Further, being able to replicate a study is critical to the research method. The authors of this study (Gulz & Haake, 2006) suggest

that guidelines be developed for reporting the look of the APA used in research so that research may be duplicated.

Study Summary

This study will investigate whether learning with an APA raises chemistry achievement, whether self-selecting an APA raises chemistry achievement, and whether self-selecting an APA affects student perception of the APA as a persona on *learner-agent relationship*, *human-like*, and *engaging* subscales.

Chemistry achievement is defined as how well the learner performs on weekly chemistry quizzes. Perception is defined as the extent to which the learner perceives the agent as a social entity while learning with the agent. Perception of the APA as a persona is defined as how the student perceives and relates to the APA on learner-agent relationship, human-like, and engaging relationship scales on the modified agent persona instrument (API) (Baylor and Ryu, 2003) (Appendix B).

Both CTML and social agency theory guidelines obtained from the literature review were applied to the design and presentation of both the learning environment and the APA. The APA was animated rather than static. Choice of APA will be available for one group, as choice is one of the topics of investigation in this study. The APA spoke, as speech has been shown to be superior to written text in most cases, although text was presented as well, keeping in accordance with integrated theory and CTML. The APA spoke the text before the text was presented onscreen, to avoid the redundancy effect. There was no extraneous material during the presentation; only text, necessary diagrams and

the APA were present. The APA used guiding gestures toward the text and diagrams and utilized facial expressions. The APA did not appear human and did not have any discernable race or gender, in order to avoid potential bias. The three APAs consisted of an anthropomorphic pig, a green alien, and a robot. The APAs were animated smoothly for realistic motion at a rate of 24 frames per second, which is standard presentation speed used in the motion picture industry.

Research Questions

This study investigated how learning with an APA affected the performance of the learner. This study also investigated whether self selection of an APA learning partner affected both the performance of the learner and their perception of the APA as a persona. Learner performance will be operationally defined as accuracy on weekly chemistry quizzes. Learner perception was operationally defined as how the learner views the APA as a persona or social entity, as measured on the modified agent persona instrument (API) survey (see Appendix B). Performance scores were measured over time through weekly quizzes, while perception scores were collected through a survey at the end of the study (see Appendix B).

Research Question 1: Do students who study with an APA achieve higher chemistry scores than students who study without an APA?

It was expected that learning with an APA would increase student performance as measured by chemistry achievement. Research has found that transfer skills may be increased when learning with an agent (Atkinson, 2002), and more recent research has found an increase in retention when learning with

agents (Dunsworth & Atkinson, 2007). As this study took place over a series of five weeks, the ability to transfer knowledge from week to week as new problems arise should have resulted in higher performance scores in the chemistry domain. Further, social agency theory suggests that students enjoy learning with agents (Nass, Isbister & Lee 2001; Lester et al., 1997; Atkinson, 2002) and experience motivational gains (Astleitner & Wiesner, 2004; Baylor & Ryu, 2003), which should have resulted in an increase in performance.

Research Question 2: Do students who study with a self-selected APA achieve higher chemistry scores than students who study using an assigned APA?

It was expected that having a choice of which APA to study with would increase student performance as measured by chemistry achievement. Choice has been found to affect performance in prior research (Moreno & Flowerday, 2005). From a Social Agency perspective, having the ability to choose your own APA is similar to having the ability to choose your own instructor. The ability to choose allows the learner to participate in the learning process and to exercise some ownership of that process (Honebein, 1996), which should have resulted in positive motivational gains and therefore performance gains.

Research Question 3: Do students who study with an assigned APA perceive the APA as more of a persona than students who study using a self-selected APA, and how do students perceive the APA in general?

It was expected that students who self-selected an APA would perceive the APA as more of a persona than students who were assigned an APA. Perception of the APA as a persona is defined as how the students perceive and relate to

the APA on *learner-agent relationship, human-like,* and *engaging* subscales on a modified API (agent persona instrument). These expectations were based on social agency theory as well as findings that choice has been shown to affect student performance. Further, allowing for choice should have increased learner satisfaction and motivation (Honebein, 1996). It was expected that this satisfaction and motivation would positively affect the social agency relationship between the student and the APA, resulting in a heightened perception of that APA as a character. Further, the students should view the APA favorably, in keeping with prior research (Atkinson, 2002; Nass, Isbister & Lee, 2001).

CHAPTER 3

METHODOLOGY

This study was designed to investigate learning with animated pedagogical agents (APAs). A basic definition of an APA is, "a computerized character (either human or otherwise), designed to facilitate learning" (Craig, Gholson & Driscoll, 2002, p.428). A common research question when APAs are involved is whether students learn more when studying with an APA. More recently, the question of choice regarding APA is beginning to be investigated (Moreno, Flowerday, & Frechette, 2005). Further, the ability of the student to choose which APA to study with has been incorporated into the design of this study, so that the effects of choice on performance and student perception of the persona of the APA can be investigated.

The overall focus of this study was whether learning with an APA improved chemistry achievement, whether the option of selecting an APA had an effect on student achievement scores and on student perception of the APA as a persona, and how the students viewed the APA in general.

The specific research questions were as follows:

1.   Do students who learn with an APA achieve higher chemistry scores than students who study without an APA?

2.   Do students who learn with a self-selected APA achieve higher

chemistry scores than students who learn using an assigned APA?

3.   Do students who learn with an assigned APA perceive the APA as

more of a persona than students who learn using a self-selected APA, and how

do students perceive the APA in general?

The design of this study employed both cognitive theory of multimedia

learning (CTML) for the layout and timing of the learning environment, and social

agency theory to design the interaction between the student and the APA. The

principles of CTML have been applied to the design of the multimedia component

of this study.

For example, CTML principles were applied when placing the APA on the

example Web page, such as the use of proximity and directing student gaze to

relevant information in a timely manner. Further, words and graphics were

located in close proximity on the example Web page in accordance with CTML,

and graphics and their corresponding explanations were never separated from

each other. Also, the APA applied CTML guidelines whenever possible. Gestures

and gaze were applied to the CTML principle of signaling, with little extraneous

movement that could be confusing or misleading to the student. Also, related

narration and animation, such as the voice and animation of the APA speaking,

were synchronized in accordance with CTML guidelines (Mayer, 2005).

Studies support the use of voice with an APA (Atkinson, 2002), especially

when presented in a natural way rather than as a monologue, which supports

CTML (Moreno, 2005). In the science domain and supporting social agency

theory, the use of APAs with voice did enhance learning (Dunsworth & Atkinson, 2007). Therefore, voice was developed for the APAs according to the principles of CTML.

Social theories regarding learner-agent interaction developed as it became apparent that learners tend to think of the APA as more of a persona or entity than as a multimedia component. Regarding a study in the computers as social actors (CASA) series, "… people apply the same interpretive strategies to interaction with embodied conversational agents (ECAs) as they do to interaction with other people." (Nass, Isbister & Lee 2001, p. 395). Therefore, learner interaction with the APA may be similar to human interaction in several ways. For example, the presence of the APA and the ability to choose which APA to study with can affect learning, perception, motivation and enjoyment (Nass, Isbister & Lee 2001; Lester et al., 1997; Atkinson, 2002). Employing social agency theory provided a framework with which to investigate the effect of learner choice on both student performance and student perception of the APA as a persona. Therefore, this study employed both CTML and social agency theory, adapting the principles of CTML that consistently apply to APA research and disregarding specific principles of CTML that do not apply to APA research. The CTML principle disregarded in this study is the split attention effect (Craig, Gholson & Driscoll, 2002), as the presence of the APA does not appear to detract from learning. Therefore, the APA appeared in addition to other educational materials rather than designing the learning environment to accommodate the split attention effect.

Web-based Learning System

An online component of a face-to-face course, a Web-based learning system (Crippen & Earl, 2007) provided the quizzing environment for this study. This Web-based quizzing environment is a criterion-referenced assessment tool which had been developed prior to this study and was refined through years of research.

Weekly quizzes contained links to example pages, which consisted of self-explanation prompts and worked examples, a format which has been shown to increase performance, problem solving skills, and self-efficacy (Crippen & Earl, 2007). The same Web-based learning system central to these prior studies was central to this study.

Each weekly quiz consisted of five multiple choice items presented on the quiz Web page. Each multiple choice item held three distracters and one correct choice. For scoring purposes, each correct choice was worth two points, for a total possible score of 10 points on each weekly quiz. For each quiz, a makeup quiz was available the following week. The makeup quiz was identical to the quiz except for the questions, which were equivalent but differed slightly. The higher score attained by the student, whether on the quiz or makeup quiz, was recorded for that week. Each of the five multiple choice items on the quiz Web page showed up to three example links. These example links were visible as buttons. By clicking on an example button, a separate worked example window was opened. A sample question with example links has been provided in Figure 2.

3. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$ is the electron configuration of

Example 1	Example 2	Example 3

○ V

◉ Zn

○ Sc

○ Ca

Figure 2. A sample question with three example buttons. When pressed, the example buttons open the worked example window.

The worked example window consisted of a self-explanation prompt, a worked example, and the APA. The self-explanation prompt appeared at the top left of the worked example window, and the worked example appeared below it, near the bottom left. While each worked example differed, each worked example applied a problem solving strategy required by the corresponding multiple choice item. The worked examples depicted how to solve problems similar to the question presented on the quiz Web page. The APA appeared on the right side of the worked example window. The APA spoke the self-explanation prompt before that prompt became visible, then guided the student with gesture and gaze to the self-explanation prompt and the worked example, see Figure 3.

Use the information below to explain to yourself the relationship between molecular and empirical formula and how this relationship is represented in other properties.

	Formula	Molar Mass
Molecular	C_8H_{10}	106.17g
Empirical	C_4H_5	53.08g
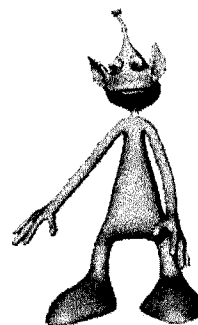
Figure 3. The worked example window displayed the self-explanation prompt, the worked example, and the APA. The APA was present only in the AA and SSA conditions. The NA condition saw this exact presentation without the APA.

The worked example window remained open until closed by the student. There was no time limit regarding how long the worked example window remained open. The student could open or close the worked example window containing the self-explanation prompt and worked example at any time during the quiz. The quiz Web page remained unchanged, unaffected by the appearance or closure of the worked example window. The student selected their answers on the quiz Web page. When the student finished the session the student clicked the submit button to send in their answers. Following this, the quiz Web page could be safely closed by the student with no loss of data.

In summary, when a student first opened the quiz Web page, the student saw five multiple choice problems. Several of these problems had example buttons. When a student clicked on one of the example buttons, the worked example window opened. In the worked example window an APA was immediately visible for students in the experimental groups. This APA audibly spoke the self-explanation prompt and gestured toward the self-explanation-prompt and the worked example. Both the self-explanation prompt and the worked example appeared as text a brief time after the APA began speaking. If the student had not been assigned to the control group and did not interact with the APA, the worked example window was identical except for the presence of the APA, and the text was not read audibly.

<div align="center">Agent Persona Instrument</div>

The Agent Persona Instrument (API) is a survey designed to measure the student's perception of the APA as a persona. Perception of the APA as a persona is defined as how a student perceives and relates to an APA on *learner-agent relationship*, *human-like*, and *engaging* subscales as measured by the modified API survey. These subscales are derived from the affective interaction construct defined by Balyor and Ryu (2005). Learner-agent relationship items are in addition to the base API and have been created for this study, as no existing survey items could be found which evaluates APA persona as perceived by the learner over a multi-session study. Learner-agent relationship items focus on APA persona and how the learner felt about the APA and is designed to accommodate a multi-session study. Human-like and engaging items come

directly from the API and the items for these subscales have not been modified for this study. The modified API used in this study is based on the latest version of the API developed by Baylor and Ryu (2005).

Initial development of the API was based upon two main constructs, informational usefulness and affective interaction (Baylor & Ryu, 1995). These constructs are helpful in understanding how students perceive the APA as a persona. Informational usefulness is the perception of the APA as a knowledgeable instructor, and affective interaction is the perception of human-like interactions with the APA. "Essentially, the human-like factor of the pedagogical agent persona is what makes it figuratively *real*. Once the pedagogical agent is perceived as virtually *real*, the engaging factor describes the positive social presence of the agent with the learner" (Baylor & Ryu, 2005, p. 309).

Informational Usefulness and Affective Interaction both consist of two factors. The two subscales that comprise Informational Usefulness are *facilitating learning*, referring to how the APA is perceived as helping the student learn, and *credible*, referring to how knowledgeable the APA is perceived to be about the material being presented. Affective Interaction consists of the subscales human-like, which refers to how well the APA communicates in a natural way, and engaging, which refers to the APA's expressions, friendliness, and ability to motivate (Baylor & Ryu, 2005). As this study investigates the affective qualities of the APA, the survey items derived from the Informational Usefulness construct have been omitted from the modified API.

Two specific groups of APA were used in the Baylor and Ryu study (2005) to refine the API and to test inter-item reliability; an agent role group and an agent image group. The agent role group used APAs working as an expert, a motivator, or a mentor. The agent image group presented one of eight APAs differing by race, gender, and realism. Using these APAs for their studies, inter-item reliability was calculated within the human-like and engaging subscales. A correlation of .86 for each of the five items in the human-like and engaging subscales indicates a high degree of inter-item reliability for these items. There were no negative correlations. Both human-like and engaging are part of the affective interaction construct, which corresponds with the APA's social presence and personality. Overall goodness of fit for this affective interaction construct met the set criterion of .05. Subjects in these studies were computer literacy students and pre-service teachers at a southeastern university, 87.5% female, and 12.5% male, the API is valid with undergraduate learners, but has not been tested with learners of other age groups. Further, the API has been deemed valid in the domains of attitudinal and procedural learning (Baylor & Ryu, 2005, p. 311).

The modified API survey used in this study consists of 20 items drawn from the three separate subscales derived from the Affective Interaction construct, collectively referred to as student perception of the APA's persona. The subscales derived from the affective interaction construct include learner-agent relationship, human-like, and engaging. Learner-agent relationship items were drawn from the framework of social agency theory and are designed to evaluate the student's perception of the APA as an individual persona. The higher the

score on this scale, the more the student perceived the APA as an individual entity or persona separate from the computer or computer program. Learner-agent relationship items are in addition to the base API and have been added to this study, as no existing survey items could be found which evaluate APA persona by the learner over a multi-session study. There are 10 items in the learner-agent relationship subscale, and include items such as, "I would like to learn with my agent in another class," and "I would like my agent to remember my name".

The human-like and engaging subscales of the modified API used in this study include all five previously developed assessment items for each subscale developed by Baylor & Ryu (2005). Human-like questions include expression and motion that can be interpreted as nonverbal communication, such as gaze and gesture. The five items in this section include items such as, "The agent was life-like," and, "The agent showed emotion." Items that assess engaging consist of five items as well, and include the items, "The agent was expressive," and, "The agent was friendly." Each survey item was presented in five point likert-type scale format, ranging as follows: 1 = strongly disagree, 2 = disagree, 3 = no opinion, 4 = agree, 5 = strongly agree. (Appendix B).

In addition to the API, open-ended student comments were collected at the end of the course. These comments were voluntary and concerned the entire course, not just the APA. When these comments pertained to the APA, a qualitative analysis was completed in an effort to understand how the students viewed the APA in general.

End of Course Survey

At the end of the course, a general survey was presented to the students as part of the curriculum. Three questions requested feedback on the course, such as how the course could be improved. Some student comments specifically mentioned the APA, and these comments were analyzed using a qualitative approach in order to discern how the student viewed the APA in general. Each student comment mentioning the APA was pooled and analyzed. General comments such as, "this was great" that did not specifically mention an APA were not included in this analysis.

The analysis consisted of a frequency count of key words and short phrases in any student comment which contained a reference to the APA. Both words and phrases were included in the frequency count, with both phrases and words assessed on the same scale. Values were assessed and assigned to these words on a scale which included negative 2, negative 1, 0, positive 1, and positive 2. If the word appeared to be neutral and held no discernable emotional component, that word was rated at 0 and deleted from the list. If the word appeared to be somewhat positive, such as the word *cute*, then a value of positive 1 was assigned to that word. If the word appeared to be somewhat negative, such as the word *time* used in the negative sense as a drain on time, then that word was assigned a value of negative 1. Similarly, if the word appeared to be highly positive regarding the APA, such as the word *liked*, then that word was assigned a value of positive 2. If a word appeared to be highly

negative, such as the word *worthless,* then that word was assigned a value of negative 2.

The frequency count was assembled into a table, and a mean was calculated to determine whether the student viewed the APA in a generally positive or negative way. A positive mean would suggest that the students viewed the APA in general in a positive way. A negative mean would suggest that the students viewed the APA in general in a negative way. Table 1 shows the survey questions (Appendix C).

Table 1

End of course survey questions.
Question
If you used the worked examples and felt they were helpful, please provide a description of a situation where the worked examples were most helpful.
If you used the worked examples, rate their effectiveness in improving your overall performance in chemistry 103.
The quizzes in chemistry 103 are intended to be learning opportunities. That's why, for instance, you have the option of changing your quiz answers throughout the week. If you consider the current quiz structure, the worked examples, and the solution suggestions: what other things could we add, or changes could we make that would help you be successful in chemistry 103?

Animated Pedagogical Agent

Three APAs were created for this study. The APAs were created to appear as believable as possible regarding their form and movement, as the appearance of the APA does influence the learner's assessment of the APA (Gulz & Haake, 2006; Lester, et al., 1997; Atkinson, 2002; Lee, Isbister & Nass, 2000). All animations including gaze and gesture were created specifically for this study and designed to flow smoothly and appear natural. A believable APA may improve motivation, and motivation can significantly influence learning (Astleitner & Wiesner, 2004).

The APA initially appeared in a neutral gesture. A neutral gesture is a relaxed pose lacking any animations. The neutral gesture was used to avoid any extraneous detail added by amusing yet unnecessary gestures or animations, as well as to avoid unintentional cues that could misdirect the student's attention (Sweller, 1994). Care was taken to create specific individual animated sequences for each APA so that when the APA did gesture and direct with gaze, the gesture was coordinated with the material being presented, in this case the self-explanation prompt and worked example (Lester et al., 1999). An example of a neutral gesture and a guiding gesture has been provided in Figure 4.
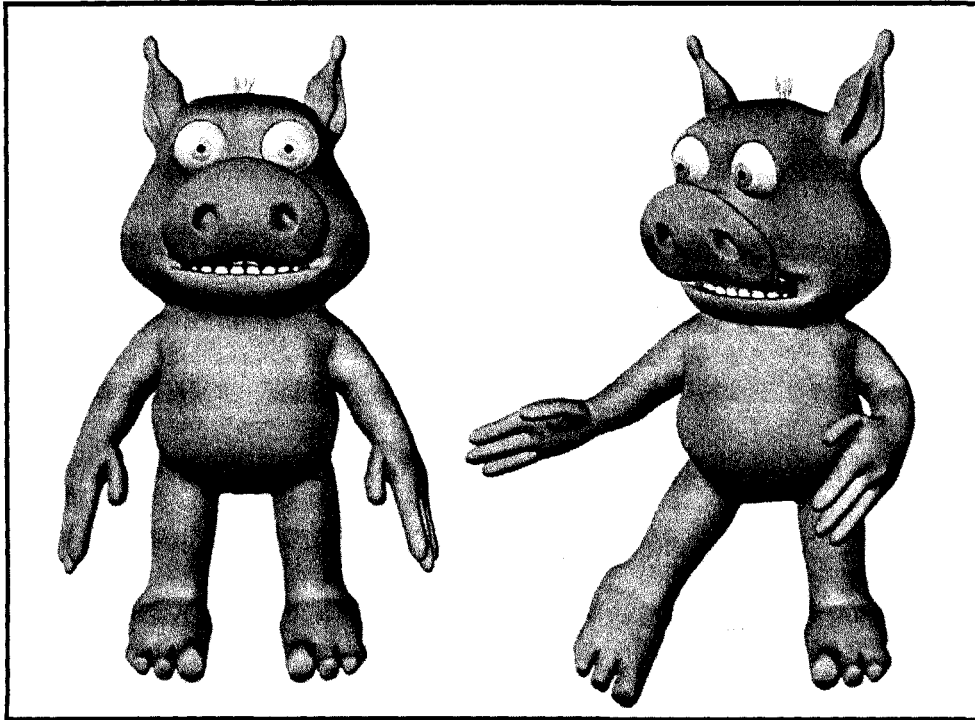
Figure 4. The APA on the left is in neutral gesture at the beginning of the animation sequence. The APA on the right is using guiding gesture and gaze.

Prior studies have shown that when students choose an APA with discernable race and gender to study with, there may be a significant decrease in student satisfaction, retention and transfer, depending upon the race and gender of the student (Moreno & Flowerday, 2005). To increase internal validity and reduce possible confounds that appear to be present when discernable race and gender are depicted, the APAs for this study were designed to be race and gender neutral. One APA was an anthropomorphic pig, another was an alien, and the third was a robot. Although each APA appeared humanoid with two arms, two legs, two eyes and one head, none of the APAs in this study could be considered

human and they lacked many discernable human traits. Each APA had an androgynous shape and unrealistic hair, eye color, and skin color.

Each APA spoke recorded human speech which had the pitch modified. The modality effect in the cognitive theory of multimedia learning (CTML) states that learning with voice is more effective than learning with text alone (Mayer & Moreno, 2003; Atkinson, 2002; Moreno, 2005). As studying with a speaking APA should be more effective than studying with an APA which did not speak, the APA spoke the self-explanation prompt each time the worked example window was opened.

Functionally, the APA always behaved as follows. The APA appeared only in the worked example window. The APA audibly read the self-explanation prompt before the text appeared on screen. The self-explanation prompt appeared after a brief delay in order to avoid the redundancy effect (Sweller, 1994), which has been noted when agents speak as the presented text is visible (Craig, Gholson & Driscoll, 2002). As the APA read the prompt and as the text appeared on screen, the APA directed the student's attention to the self-explanation prompt and worked example with gesture and gaze. After the APA had concluded both reading and gestures, the APA returned to a neutral position and became inactive, although still visible until the window was closed by the student.

Research Design

This study investigated three questions regarding learning with APAs. The first question pertained to whether or not interacting with an APA affects chemistry achievement. The second question asked whether or not self-selecting

an APA to study with affects chemistry achievement. The third question asked whether self-selecting an APA to study with affected the student's perception of the APA as a persona, and how students perceived the APA in general. To answer these questions, this study used a quantitative, quasi-experimental design with repeated measures. Open-ended student comments regarding their views on the course were analyzed using a qualitative approach when these comments pertained to the APA.

It was expected that students who studied with an APA would significantly increase chemistry achievement over the control group on criterion-referenced tests.

It was expected that students who studied with self-selected APAs would significantly increase chemistry achievement over the assigned APA group on criterion-referenced tests.

It was expected that students who studied with self-selected APAs would score significantly higher over the assigned APA group on the API, and it was expected that in general, students would view the APA favorably, in accordance with the literature review.

The first and second research questions were analyzed using a one-way repeated measures analysis of variance (ANOVA). The third research question was analyzed using an independent samples t-test. Further, comparisons for individual items on the API survey were also performed using a t-test and a one-way analysis of variance (ANOVA) with a Tukey HSD as a follow-up test, comparing the assigned agent (AA) and self-selected agent (SSA) groups for any

significant differences regarding these individual items. Open-ended comments which mentioned the APA were analyzed. A qualitative approach was applied to all comments that mentioned the APA in order to discern how the student felt about the APA in general. Specific words about the APA that were easily discernable as negative or positive were rated on a likert-type scale with values ranging from negative two as very negative, negative one as negative, zero as neutral, one as positive, and two as very positive. In addition to rating the words, interpretations were formulated in an effort to explain why the views of the student did not align with theory, as presented in the review of the literature.

The sample of students who participated in this study was one of convenience rather than random assignment. This sample of convenience may not represent the population; therefore the design of this study was quasi-experimental. Due to the quasi-experimental nature of this study, no causality could be inferred from the results of this study regarding any of the three research questions, despite possible significant results. However, trends and correlations were investigated.

By increasing the amount of data collected, the power of the study was increased. The range for each weekly quiz was from 0 to 10. As this study took place over five weeks, the range of the chemistry achievement data collected for all five quizzes could have been increased to 0 – 50. If there had been only one session, the range would have spanned 0-10, so increasing the range to 0-50 increased the power of the study. This made it more likely to find significant differences, should they exist between the groups being compared, when the

data was analyzed. However, as one week held no quiz due to technical difficulties, as data from only four quizzes were collected to be analyzed, the range was 0 – 40.

Course Description

The course in which the intervention took place was Preparatory Chemistry, chemistry 103, presented at a large, southwestern university. This course is for students who wish to take General Chemistry I, but have a deficiency in high school chemistry. The course had two main components; a lecture series and a laboratory component.

The course consisted of 3 hours of laboratory and 3 hours of lecture each week. Students were present in person during the laboratory and lecture. Interaction with APAs took place through the quizzes on the Web-based learning system, and course evaluation consisted of three midterm exams, online quizzes, group quizzes, and laboratory activities. The 12 online quizzes counted toward 14% of the total grade.

Online content was provided through WebCampus, a university portal for students and faculty. Various resources were available to students through the WebCampus course page, such as the course materials folder which contained lecture outlines, study guides, and practice material. The syllabus was accessible, as were links to the Web page for the course textbook as well as a practice problems page. Interactive dialogs, online viewers, and other student resources were also available. Quizzes were accessible through WebCampus, which accessed the Web-based learning system.

Measures

The independent variable in this study was the presence of the APA, indicated by the condition to which the student had been assigned. The two dependent variables were chemistry achievement as measured by performance on weekly, online, multiple-choice chemistry quizzes, and the score on the API regarding how the student viewed the APA as a persona. Multiple measures were taken as data was collected from four weekly quizzes in total. Five quizzes were planned, but one quiz was a repeat due to technical difficulties and so the data from that week was disregarded. The API survey took place only once, at the conclusion of the study. All of the data and assignments collected in this study were stored in a database created specifically for this study. Open-ended student comments solicited at the end of the course, regarding the course in general, were also utilized in this study. Some of these comments mentioned the APA, and these comments were analyzed using a qualitative approach in order to discern how the student viewed the APA in general.

In addition to chemistry achievement gathered by the quiz, the database recorded which APA condition was assigned to the subject in the AA condition and the choice of APA for the SSA condition. If the learner requested a change of condition, this was recorded by the database, however no learner requested a change of condition throughout the study. A breakdown of materials, treatment and data collection by assigned condition is shown in Table 2, while Table 3 shows the theoretical framework of this study as well as the mode of presentation according to the assigned condition.

Table 2

Methodology table showing theory and mode.

Condition	Theory	Mode
NA	CLT and CTML	Text
AA	CLT, CTML, Social Agency	Animation, audio, text
SSA	CLT, CTML, Social Agency	Animation, audio, text

Table 3

Methodology table showing treatment and data analysis.

Condition	Treatment	Data collection	Analysis
NA	No APA	Quizzes	ANOVA
AA	APA	Quizzes, API, survey	ANOVA
SSA	APA	Quizzes, API, survey	ANOVA, t-test

Procedure

Overview

This study consisted of three phases. The first phase was the assignment phase in which students enrolled in the chemistry 103 course were randomly assigned to groups. Development was the second phase, which focused on the initial testing of the APAs over a five week period prior to the main study. The third phase was data collection and took place immediately after the conclusion of the development phase so that no student services were interrupted. Transition from the development phase to the main study was transparent to the students. The resulting data was from 4 weeks of recorded quizzes, one week had to be disregarded due to technical difficulties, and the API survey.

The three conditions in this study were the NA control group (NA), the assigned APA group, and self-selected APA group. Treatment in this study was exposure to the APA. Exposure to the APA took place during the weekly quizzes as part of the chemistry 103 course curriculum. While all of the educational materials remained the same for each student, only the experimental groups were exposed to the APA. All of the data from the quizzes and the API survey were recorded to a database and analyzed at the conclusion of the study.

Assignment

All participating students were enrolled in the chemistry 103 course. When the student initially accessed the Web-based learning system online through WebCampus, the student was presented with an experimental consent form (Appendix A). Each participating student completed the consent form in order to

participate in the study, and was randomly assigned to an experimental condition. If the student did not click agreement on the consent form, or did not wish to participate in the study, the student was still assigned to a condition but did not participate in the study, and any data obtained from that student was not analyzed.

Students enrolled in the chemistry 103 course were randomly assigned to a control group or one of two experimental conditions when the Web-based learning system was initially accessed: a control group which did not include an APA (NA), an experimental group with an automatically assigned APA (AA), and an experimental group with a self-selected APA (SSA). This assignment took place at the onset of the study as the student clicked on an example button for the first time, and was transparent to the student.

If an APA was assigned to the learner, then the APA was present in every worked example window that the student viewed. The student studied with the APA by viewing and listening to that APA in the worked example window, accessible through the quiz Web page. Every student, including students not participating in the study, viewed the same quiz and worked example window with the identical self-explanation prompt and worked example.

Students in the NA control group were not assigned an APA. These students did not interact with any APA throughout the study. As the control group, the experience of the student was identical in every regard to a student in the class who did not participate in the study.

Students in the AA group interacted with an APA. Each student in the AA group was assigned an APA randomly, from one of three possible APAs. This assignment was transparent to the student. The students in the AA group studied only with their assigned APA, and never viewed the other possible APAs.

Students in the SSA group studied with an APA of their choice. Each student in the SSA group selected the APA they wished to interact with after previewing all three of the potential APAs in a separate window. This APA assignment was chosen by the student, who interacted with the chosen APA. The SSA group differed from the AA group only in this initial method of APA assignment. Figure 5 shows the initial selection available to students in the SSA condition.
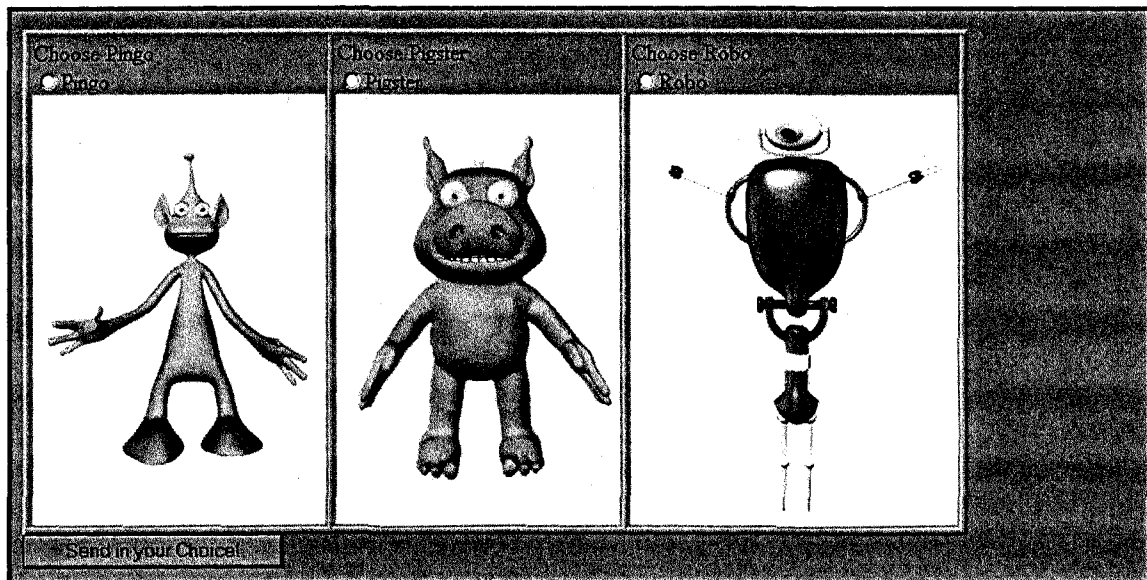
Figure 5. Choice of APA window for the SSA condition.

Regardless of the experimental condition assigned, each student received identical instruction and access to course materials, including all of the worked

examples and self explanation prompts available through the Web-based learning system. If the student participated in the study initially but wished to withdraw from the study at any time, the student was free to do so without penalty and could finish the course normally. However, no student withdrew from the study, or asked to have their APA changed or removed.

Exposure to the APA took take place during the weekly quizzes as part of the preparatory chemistry course curriculum. While all of the educational materials remained the same for each student, only the experimental groups were exposed to the APA.

To summarize, the students in the control group did not interact with an APA. Students in the AA and SSA groups did interact with an APA. Each student in the AA group had an APA assigned randomly. Each student in the SSA group selected their own APA to study with. The condition to which the student had been assigned was immediately recorded to the database, and neither the condition nor the APA assignment changed throughout the study.

Development

The APAs were introduced in quiz week four of the semester for the development phase, but were not initially available to the students at that time. Care was taken to ensure that the APAs were designed and implemented in accordance with both CTML and social agency theory, and the APAs were adjusted during this time for placement, timing, voice and gesture. During this period, the APAs were used for offline testing only, including checks for programming and animation errors for a period of approximately four weeks.

This testing was necessary to ensure that when the APAs and database system went live to several hundred students, most of the errors would be corrected to avoid potential confounds as the main study began. Because of this, the APAs were tested thoroughly to ensure that they functioned exactly as they would when they went live.

There were two parts to the development phase. The first part involved the mechanics of designing and programming the APA into the example page and checking the APAs functionality. This included accurate animation, sound, placement and database programming, to ensure compliance with CTML and social agency theory. These troubleshooting tests were performed by the author of this study and supporting professors involved in the study. While several student dummy accounts were created to test the mechanics of integrating the APA, no students interacted with the APA during this time.

Difficulties encountered during the first phase of development included database issues leading to minor revisions, and a revised numbering system used to reference the example library. Placement of the APA, timing, and voice issues were resolved in accordance with CTML and social agency theory. A visible email address was added to the initial log-on screen, in case the student wished to report a problem or an error, or to withdraw from the study. This option was never used, but remained available throughout the study.

The second part of the development phase followed 2 weeks later, and involved going live to all of the participating students and recording their information to the database. At that time, although the APAs were functioning as

desired, the database and system functionality had to be tested with the maximum number of students participating in the study. All students were processed and participating students were assigned to a group, and the information was recorded to the database. Further minor adjustments took place at this time, most notably an effort to streamline APA animation, voice, and example page integration to ensure a smooth and timely transition from quiz to quiz.

Data Collection

After the development phase was completed, the data collection phase consisted of four quizzes out of a planned five, the API survey, and open-ended student comments that specifically mentioned the APA. After the last quiz had been completed, the API survey to measure student perception of the APA as a persona was administered online. API surveys were only given to students who had been assigned to APA conditions. Open-ended comments were also solicited at this time, regarding the chemistry 103 course in general. All of the data recorded to the database throughout the data collection phase of the study was used for analysis.

Data Analysis

The first research question asked whether there was a statistically significant difference in chemistry achievement for students who studied with an APA compared to students who do not study with an APA. For this question, the comparison was between the NA control group and the APA groups, consisting of the AA and the SSA groups. The independent variable was the condition to

which the learner has been assigned. The dependent variable was performance as measured by the chemistry achievement score on the weekly quizzes. As the quizzes took place over 5 consecutive weeks and each student took the same quiz, using an ANOVA was appropriate. Any detected significant difference at the .05 level would indicate that there was a difference between the groups, and that the presence of an APA while learning chemistry may have been a contributing factor which influenced student performance as measured by chemistry achievement. The significance level of .05 percent has been chosen as this is a matter of convention. "Researchers generally have not considered relaxing the standard significance level (alpha = .05) and adopting less stringent levels (for example, alpha = .10 or .25)" (Keppel, 1973 p. 81)

Between-Groups comparisons in the ANOVA, the NA, AA, and SSA groups were analyzed for significant differences as well as secondary effects. A Tukey post-test for linear analysis was to be completed for the analysis of both the first and second research questions to see if there had been a change in APA effectiveness, provided a significant difference was revealed in the ANOVA.

The second research question asked whether there was a statistically significant difference in chemistry achievement for students who studied with an assigned APA compared to students who studied with a self-selected APA. This question was analyzed using the same ANOVA used to analyze the first question. The independent variable was the condition to which the learner has been assigned. The dependent variable was performance as measured by the chemistry achievement score on the weekly quizzes. In the case of this second

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research question, the main comparison was between the two APA groups, as the AA group was assigned an APA randomly and the SSA group was able to self-select their APA. Significant results at .05 would have indicated that there was a difference in performance as measured by chemistry achievement between students who were assigned an APA and students who self-selected their APA.

The third research question asked whether learner choice regarding which APA to study with could affect learner perception of that APA as a persona, and asked how students perceived the APA in general. The independent variable was the condition to which the learner has been assigned. The dependent variable was the score on the modified API survey. The relevant groups were the two conditions who interacted with an APA. The main comparison was made between students who self-selected an APA and students who were assigned an APA randomly. This was analyzed using a two sided, independent samples t-test. The two sided t-test was used in order to detect a significant difference if the self-selected group outperformed the assigned group, or if the assigned group outperformed the self-selected group. A two sided test was appropriate as choice has been shown to have negative effects in some cases (Moreno, Flowerday & Frechette, 2005).

A significant main effect would indicate that there was a difference in student perception of the APA as a persona between these two APA groups. As the API survey had three subscales that made up the student's perception of the APA as a persona, comparisons were been made between the AA and SSA groups for

each of these categories through a t-test analysis at the standard .05 significance level. These categories included learner-agent relationship, human-like, and engaging. Further, comparisons for individual items on the API survey were also performed using a t-test and an ANOVA with a Tukey HSD as a follow-up test, comparing the AA and SSA groups for any significant differences regarding these individual items.

Open-ended comments were solicited at the end of the chemistry 103 course as part of the chemistry 103 curriculum, regarding the course in general. If the comment mentioned the APA, their comments were analyzed. A content analysis was applied to all comments that mentioned the APA in order to discern how the student felt about the APA in general. Specific words about the APA that were easily discernable as negative or positive were rated on a likert-type scale with values ranging from negative two (-2) as very negative, negative one (-1) as negative, zero as neutral (0), one as positive (1), and two (2) as very positive. In addition to rating the words, interpretations were formulated in an effort to explain why the views of the student did not align with theory, as presented in the review of the literature.

Regarding a possible confound, it may be likely that one APA was simply more or less appealing than the other APAs. To find out if the students preferred one APA over the other, an ANOVA was conducted on the self-selected APA group to discover if there was a significant difference in student choice of APA.

As the study took place through four quizzes over 5 weeks, it was hoped that the additional data collected over time would provide sufficient power to detect a

significant difference between groups at the .05 level should such a difference exist. It was also hoped that the additional time allocated to this study would assist in revealing student preferences in learning with APA's over a prolonged period of time.

Anticipated Results

It was expected that learning with an APA would increase student performance as measured by chemistry achievement. Learning with an APA can increase chemistry achievement in the science domain (Dunsworth & Atkinson, 2007).

It was expected that having a choice of which APA to study with would increase chemistry achievement. Prior research has shown that choice of APA can positively affect achievement in some cases (Moreno & Flowerday, 2005). It is possible that certain negative results from the Moreno and Flowerday study (2005) were due to the very human appearance of the APAs and the race and gender specific appearances applied to these APAs. By using APAs that are not human and have no discernable race or gender, race and gender specific confounds may have been avoided in this study. As the negative effects of choice were race and gender based, it was anticipated that the effects of choice in this study would be positive overall.

It was expected that students who self-selected an APA would perceive the APA as having a stronger persona than students who were assigned an APA. Perception of the APA as a persona was defined as how the students perceived and related to the APA on learner-agent relationship, human-like, and engaging

subscales on the modified API. These expectations were based on social agency theory as well as prior findings that choice has been shown to affect performance.

Further, allowing for choice should have increased learner satisfaction (Honebein, 1996). It was hoped that this increase in satisfaction would positively affect the social agency between the learner and the APA, resulting in a greater perception of that APA as a persona. In addition, general comments regarding the APA were expected to be positive, as students tend to enjoy learning with an APA (Lester et al., 1997; Atkinson, 2002).

CHAPTER 4

RESULTS

Introduction

This study was designed to investigate learning with animated pedagogical

agents (APAs) in the chemistry domain. A basic definition of an APA (Animated

Pedagogical Agent) is, "a computerized character (either human or otherwise),

designed to facilitate learning" (Craig, Gholson & Driscoll, 2002, p.428). The

ability of the student to choose which APA to study with has been incorporated

into the design of this study, so that the effects of student choice on performance

and perception of the APA could be investigated. Further, the student's view of

the APA in general was analyzed from open-ended comments submitted by the

students.

The design of this study employed both the cognitive theory of multimedia

learning (CTML) for the layout and timing of the learning environment and social

agency theory to design the interaction between the student and the APA. The

learning environment and presentation of the APA was designed in accordance

with CLT (Sweller, 1994) and CTML (Mayer, 2005).

The basic tenants of CLT are that there are dual channels, that processing

capacity is limited, and that learning is active. CLT introduced the concept that

there is a cognitive processing cost for each element that is presented. CTML

built upon these CLT concepts, and CTML has been drawn from many existing theories (Mayer, 2005). Cognitive load theory is a core component of CTML. CTML specifically applies these tenants to multimedia. Because of its multimedia emphasis, CTML is an effective framework to apply when designing an APA presentation.

Social theory regarding the APA developed to accommodate the finding that motivation and enjoyment increased when learning with an APA (Lester et. al., 1997). Social agency theory states that interacting with an APA brings about the learner's social views and expectations of that interaction (Dunsworth & Atkinson, 2007). The learner views the APA as more of an entity rather than a component of the program (Nass & Moon, 2000). The persona effect is the concept that the presence of the APA can directly affect the learner's view of the educational experience. The persona effect implies that the learner views the APA as having certain personality characteristics, and the persona effect is noted when the APA can influence the learner's view on learning (Lester et. al., 1997). Suggestions to make the APA appear more believable support both the persona effect and social agency theory (Lester, Voerman, Towns, & Callaway, 1999; Nass, Isbister & Lee, 2001).

Based on guidelines suggested by CTML, the presentation of speech appears to be influenced by the presence of the APA (Atkinson, 2002). The APA influences the learner's emotion, motivation and emotion (Moreno, Mayer, Spires & Lester, 2001). Also, the ability to choose which APA to study with has been shown to affect learning (Moreno, Flowerday & Frechette, 2005).

Both CTML and social agency theory are applicable when designing APA presentations. Therefore, both were utilized in this study in order to maximize the educational potential of the learning environment. The design and presentation of the APAs created for this study also relied on the guidelines of both CTML and social agency theory.

The subjects of this study are described below, followed by the results of the development phase which attempted to apply both CTML and social agency theory to the design and presentation of this study. An in depth analysis of each of the three research questions follows their brief review, and the statistical results for each research question are presented. The results are summarized at the end of the chapter.

Subjects

The subjects consisted of 174 students enrolled in a single Preparatory Chemistry course, chemistry 103. Based upon class data, biology was the predominant major at 32.5%, including biochemistry. Chemistry was well-represented at 11%, engineering was at 10% including civil, electrical, mechanical and undeclared engineering. Kinesiology, pre-computer science and Nursing each represented 5% of the sample population. Psychology represented 4%. Other majors represented with more than two students each included kinesiology, architecture and art. Those with undeclared majors represented 11% of the subject population, as presented in Table 4.

Table 4

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Subject demographics.

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Major	Percent
biology	32.5
chemistry	11
engineering	10
kinesiology	5
pre-computer science	5
nursing	5
psychology	4
undeclared	11
other	16.5

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The standing of the students was predominantly freshman at 40%, followed by 33% sophomores, 15% juniors and 10% seniors, with two graduate students and three non-specified. The total number of students participating in this study was 174. Out of this, 157 students completed the study.

There were three conditions in this study. The NA condition was the control group, the AA condition had an APA selected by random assignment, and students in the SSA condition selected their choice of APA to study with.

Students in the NA control group were not assigned an APA. These students neither viewed nor interacted with any APA throughout the study. As the control group, the experience of the student in the control group was identical in every regard to a student in the class who did not participate in the study. A total of 75 students assigned to the no agent control group completed the study.

Students in the AA group interacted with an APA. Each student in the AA group was assigned an APA randomly, from one of three possible APAs. This assignment was transparent to the student. The students in the AA group studied only with their assigned APA. A total of 51 students assigned to the assigned APA group completed the study.

Students in the SSA group studied with an APA of their choice, as each student in the SSA group selected the APA they wish to study with. The student interacted only with the selected APA. The SSA group differed from the AA group only in this initial method of APA assignment. A total of 31 students assigned to the self-selected APA group completed the study, shown in Table 5.

Table 5

Number of students per group.

Assigned group	n
NA	75
AA	51
SSA	31

Development Phase Results

A development phase was conducted for the first 5 weeks of this study to ensure that the technical requirements of the study were being met and to ensure that the learning environment conformed to CTML and social agency theory. This development phase included making certain that the database was fully functional, the APA's were presented with believable animations, voice synchronization was acceptable, the APAs appeared as expected, the presentation of the self-explanation prompts and the APAs were coordinated, the presentation of both the learning environment and the APA was in accordance with CTML and social agency theory, and that each worked example window functioned as expected throughout the quiz.

During the early phases of the development, voice was not included in the design of this study. However, studies support the use of voice with an APA (Atkinson, 2002), especially when presented in a natural way rather than as a monologue, which supports CTML (Moreno, 2005). In the science domain and supporting social agency theory, the use of APAs with voice enhanced learning (Dunsworth & Atkinson, 2007).

Therefore, voice was developed for the APAs. The voice was slightly modulated, so that while it was easily discernable, it could be believed to have originated from the APA in question, whether pig based, alien based, or robotic. However, in accordance with the CLT and CTML guideline to avoid redundancy, the APA spoke the self explanation prompt for 30 seconds before that prompt appeared in the worked example window. The delivery of the APAs voice was enabled in the development phase, and was in accordance with both CTML and social agency theory.

The appearance of the APA was carefully designed. Animation was required, as believability in developing APAs may increase their effectiveness (Lester et al., 1999; Gulz & Haake, 2006) and animation can result in an increase in student motivation whereas static images do not (Baylor & Ryu, 2003). Therefore, the APAs were animated throughout the entire presentation. Animations consisted of appearing to read the self-explanation prompts and leading the students with gesture and gaze, as suggested by prior studies (Atkinson, 2002; Clark & Choi, 2005).

Throughout the development period, the animated sequences for the APAs continued to develop in an effort to increase believability. The APA should appear as lifelike as possible, and this concept applies to both human and non-human APAs (Moreno, Mayer, Spires & Lester, 2001; Lester, Voorman, Towns & Callaway 1999). Several animated sequences were created for each APA, and various sections from these animations were applied to the appropriate example Web pages in an effort at creating realism, smooth motion, and believability in accordance with social agency theory.

CTML principles were applied when placing the APA on the example Web page, such as the use of proximity and directing student gaze to relevant information in a timely manner. Further, words and graphics were located in close proximity on the example Web page in accordance with CTML, and graphics and their corresponding explanations were never separated from each other. Also, the APA applied CTML guidelines whenever possible. Gestures and gaze were applied to the CTML principle of signaling, with little extraneous movement that could be confusing or misleading to the student. Also, related narration and animation, such as the voice and animation of the APA speaking, were synchronized in accordance with CTML guidelines during this development phase (Mayer, 2005).

The split attention effect states that an increase in cognitive load should result from the inclusion of the APA. This does not appear to be the case (Craig, Gholson & Driscoll, 2002). Therefore, for the purpose of this study and regarding

the inclusion of the APA in the example Web page, the concept of the split attention effect was not a design factor.

During the development phase, this study attempted to apply CTML and social agency theory in the maximum amount possible. The only exception was the exclusion of the split attention effect already noted. Therefore, it was hoped that results from this study would imitate prior research. Performance would increase, and the students would enjoy their interaction with the APAs.

Research Questions

A review of the literature led to three distinct, yet related research questions regarding learning with APAs. The first question pertained to whether or not interacting with APA would affect chemistry achievement. Chemistry achievement is measured by the student's chemistry scores on weekly, multiple-choice quizzes. The second question asked whether or not self-selecting an APA to study with affected chemistry achievement. The third question asked whether self-selecting an APA to study with affected the student's perception of the APA as a persona, and analyzed additional student comments regarding their perception of the APA in general. Perception of the APA as a persona is defined as how the students perceive and relate to the APA in learner-agent relationship, human-like, and engaging subscales, and was measured through the modified agent persona instrument (API) initially developed by Baylor and Ryu (2005). To answer these questions, this study used a quantitative, quasi-experimental design with repeated measures. Open-ended student comments regarding their views on the chemistry 103 course were analyzed using a qualitative approach

when these comments pertained to the APA. Formally stated, the research questions read as follows:

1. Do students who study with an APA achieve higher chemistry scores than students who study without an APA?

2. Do students who study with a self-selected APA achieve higher chemistry scores than students who study using an assigned APA?

3. Do students who study with an assigned APA perceive the APA as more of a persona than students who study using a self-selected APA, and how do students perceive the APA in general?

This study had three conditions. The NA condition was the control group, the AA condition had an APA selected by random assignment, and students in the SSA condition selected their choice of APA to study with.

Research Question Analysis

The first and second research questions were analyzed using a one way, between groups, multiple measures Analysis of Variance (ANOVA) to determine whether or not a significant difference existed between the groups. All of the groups were compared in this question, NA, AA, and SSA. In addition to major effects, secondary effects were studied as well, to see if there were significant differences between specific groups.

The third research question, comparing student perception of the APA as a persona between self-selected and assigned APA groups and discerning how the APA was viewed in general by the students, was analyzed using a two way t-test between the AA and SSA groups based upon student scores in the API. Each

95

individual item in the API was analyzed using a t-test in an effort to discern if any item elicited significantly different responses from the AA and SSA groups. Another t-test was used to compare the AA and SSA groups against the three subscales used in the API survey, learner-agent relationship, human-like and engaging, to determine if any of the subscales differed significantly between the two groups. To determine if the type of APA had an effect on the survey, an analysis was made using the Tukey HSD as a follow-up test.

Further, open-ended student comments solicited at the end of the course regarding the course in general were utilized in the analysis for this research question. Some comments specifically mentioned the APA, and these comments were analyzed using the qualitative approach of word weighting in order to discern how the student viewed the APA in general. The overall focus of this study was whether learning with an APA improved chemistry achievement, whether the option of selecting an APA had an effect on student achievement scores and on student perception of the APA as a persona, and how the students viewed the APA in general.

Chemistry Achievement and the APA

The first research question asked whether there is there a statistically significant difference in chemistry achievement for students who studied with an APA compared to students who did not study with an APA. It was expected that studying with an APA would increase student performance as measured by chemistry achievement. Comparisons were made between the NA control group and both of the APA groups, consisting of the AA and the SSA groups. The

independent variable is the condition to which the learner has been assigned. Performance as measured by the chemistry achievement score on the weekly quizzes is the dependent variable. The four quizzes took place over 5 consecutive weeks and each student took identical quizzes. As three groups were compared, a one way ANOVA was appropriate. Any detected significant difference at the .05 level would have indicated that there was a difference between the groups, and that the presence of an APA while learning chemistry could have been a contributing factor which influenced student performance as measured by chemistry achievement. The significance level of .05 percent was chosen as this is a matter of convention. "Researchers generally have not considered relaxing the standard significance level (alpha = .05) and adopting less stringent levels (for example, alpha = .10 or .25)" (Keppel, 1973, p. 81).

A one-way ANOVA was conducted to evaluate the effect of studying with an APA on chemistry achievement. Chemistry achievement consisted of the cumulative score of four weekly quizzes. Table 6 presents the descriptive statistics.

Table 6

Descriptive statistics for chemistry achievement by APA group.

APA group	n	$\underline{M}$	$\underline{SD}$
NA	75	24.05	12.46
AA	51	25.80	12.66
SSA	31	25.55	13.02

The results of the ANOVA revealed no significant difference in chemistry performance between students who studied with an APA and students who did not study with an APA. When comparing chemistry performance between the AA, SSA and control group, no significant differences were found, $F(2,154) = .339$, $p = .713$. Tukey post-hoc comparisons between each of the three groups showed no significant differences between any of the groups.

Chemistry Achievement and Choice of APA

The second research question asked whether there was a statistically significant difference in chemistry achievement for students who studied with an assigned APA compared to students who studied with a self-selected APA. It was expected that self-selecting an APA to study with would increase chemistry

achievement. This question was analyzed using the same ANOVA used to analyze the first research question. The independent variable is the condition to which the learner has been assigned. Performance as measured by the chemistry achievement score on the weekly quizzes is the dependent variable and the repeated measure. In the case of this second research question, the main comparison was between the two APA groups, as the AA group was assigned an APA randomly and the SSA group was able to self-select their APA. Significant results at .05 would indicate that there was a difference in performance as measured by chemistry achievement between students who were assigned an APA and students who selected their own APA.

The analysis for this question is identical to the prior question. No significant results were revealed between the groups $F(2,154) = .339$, $p = .713$. Tukey post-hoc comparisons between each of the three groups showed no significant differences between any of the groups at p < .05. There appears to be no significant difference in chemistry performance between students who study with an assigned APA and students who study with a self-selected APA.

Choice of APA, Perception of Persona, View of the APA

The third research question asked whether self-selecting an APA to study with could affect learner perception of that APA as a persona. It was expected that students who self-selected an APA would perceive the APA as having a greater persona than students who were assigned an APA. The independent variable is the condition to which the learner has been assigned. The dependent variable is the measure of persona as calculated by the score on the modified

API survey, which consists of the three subscales, learner-agent relationship, human-like and engaging. The relevant groups are the two conditions which interact with an APA, the AA and the SSA groups. Incomplete surveys were discarded.

The main comparison was between students who self-selected their own APA and students who were randomly assigned an APA. The scores on the API survey to measure student perception of APA persona were relatively low. Each of the twenty items ranged from one to five on the likert-type scale, but the overall mean was low both for the AA group (M = 50.47) and for the SSA group (M = 44.47). The results were analyzed using an independent samples t-test. The t-test was two sided in order to detect a significant difference regardless of which group outperformed the other.

A significant result would indicate that there is a difference in student perception of the APA as a persona between the AA and the SSA groups. Each individual item was compared as well, to determine if the two groups differed significantly on certain items in the API. An independent samples t-test of the cumulative scores on the API survey revealed no significant difference in perception of APA persona between the 30 subjects in the AA group (M = 50.47, SD = 17.70) and the 15 subjects in the SSA group (M = 44.47, SD = 17.06, t(43) = 1.084, p = .284).

The results of comparing groups on each item of the API revealed significant results for only item 10 between the AA group (M = 3.47, SD = 1.33) and the SSA group (M = 2.53, SD = 1.06, t(43)=2.36, p=.023). Item 10 read, "Would you

like to be able to customize your agent". Item 10 is a question in the learner-agent relationship subscale.

The AA and SSA groups were compared in a t-test to determine if the three subscales on the API differed significantly whether the APA was randomly assigned or self-selected. The three subscales were learner-agent relationship, human-like and engaging. No significant differences in perception of APA persona were detected between the APA groups on these three subscales. Scores on the learner-agent relationship subscale between the AA group (M = 24.83, SD = 9.16) and the SSA group (M = 21.60, SD = 6.48, t(43)=1.14, p>.05), the human-like subscale between the AA group (M = 12.13, SD = 4.45) and the SSA group, (M = 11.60, SD = 4.42, t(43)=.380, p>.05) and the engaging subscale on the AA group (M = 13.5, SD = 5.01) and the SSA group (M = 11.27, SD = 4.86, t(43)=1.42, p>.05) did not appear to differ significantly.

After comparing the AA and SSA groups, a one-way ANOVA was conducted to determine if there were significant differences based on the APA assigned, whether by student selection or random assignment, on perception of the APA as a persona as measured by the API. The groups compared for this ANOVA were categorized by the actual APA the student used during the study; the alien APA Pingo, the pig-like APA Pigster or the robotic APA Robo. An overall ANOVA between the three APAs revealed no significant differences regardless of the APA assigned to the learner ($F(2,42) = 3.09$, $p =.056$). A tukey post-hoc follow-up test was performed, revealing a significant difference between the APAs Pingo and Robo, with Robo scoring significantly higher in persona according to

the API survey, and Pingo scoring lowest in persona overall. Descriptive statistics appear in Table 7.

Table 7

Descriptive statistics for persona by APA group.

APA group	n	M	SD
Pigster	17	57.00	10.19
Pingo	16	41.19	18.20
Robo	12	49.29	18.84

A one-way ANOVA was further conducted to determine if there was a statistically significant difference in the subscales of the API compared to the APA assigned. The results of this analysis were significant in the first and third API subscales. There appears to be a significant difference in the API subscales depending upon which APA was paired with the learner. The first and third subscales were learner-agent relationship ($F(2,42) = 3.72$, $p = .032$) and engaging ($F(2,42) = .3.25$, $p=.049$). Descriptive data appears in Tables 8 and 9.

Table 8

Descriptive statistics for the learner-agent relationship subscale.

Learner-agent	n	$\underline{M}$	$\underline{SD}$
Pigster	17	27.67	6.31
Pingo	16	19.31	8.65
Robo	12	25.18	9.52

Table 9

Descriptive statistics for the engaging subscale.

Engaging	n	$\underline{M}$	$\underline{SD}$
Pigster	17	12.88	5.34
Pingo	16	10.69	5.13
Robo	12	15.33	3.14

When the APA was compared with each item on the API in a one-way ANOVA, there were several significant results. Six items on the API differed significantly depending upon the APA paired with the learner in this study. The APA had a significant effect on item one ($F(2,42) = 4.34$, $p=.019$), item three ($F(2,42) = 6.77$, $p=.003$), item four ($F(2,42) = 3.34$, $p=.045$), item 16 ($F(2,42) = 3.26$, $p=.048$), item 17 ($F(2,42) = 3.14$, $p=.054$), and item 19 ($F(2,42) = 4.40$, $p=.018$). Descriptive statistics appear in Table 10 and Table 11.

Table 10

Descriptive statistics for questions 1, 3 and 4 of the modified agent persona instrument.

Question 1	n	M	SD
Pigster	17	1.88	.93
Pingo	16	1.19	.54
Robo	12	1.92	.79

Question 3	n	M	SD
Pigster	17	2.41	1.12
Pingo	16	1.75	1.06
Robo	12	3.17	.712

Question 4	n	M	SD
Pigster	17	2.71	1.26
Pingo	16	2.00	1.15
Robo	12	3.08	.90

Table 11

Descriptive statistics for questions 16, 17 and 19.

Question 16	n	M	SD
Pigster	17	2.53	1.12
Pingo	16	2.06	1.12
Robo	12	3.08	.79

Question 17	n	M	SD
Pigster	17	2.35	1.06
Pingo	16	2.13	1.45
Robo	12	3.08	.79

Question 19	n	M	SD
Pigster	17	2.65	1.17
Pingo	16	1.88	1.02
Robo	12	2.65	1.17

Post-hoc comparisons using the Tukey as a follow-up test revealed that in each of these significant cases, the alien APA Pingo scored lower than both the Pig-like APA Pigster and the Robotic APA Robo in perception of persona. Robo scored highest in perception of persona in each of these significant cases.

At the end of the course, a general survey was presented to the students as part of the curriculum. Three questions requested feedback on the course, such as how the course could be improved. Some student comments specifically

mentioned the APA, and these comments were analyzed using a qualitative approach in order to discern how the student viewed the APA in general.

The analysis consisted of a frequency count of key words and short phrases in any student comment which contained a reference to the APA. Both words and phrases were included in the frequency count, with both phrases and words assessed on the same scale. Values were assessed and assigned to these words on a scale which included negative 2, negative 1, 0, positive 1, and positive 2. If the word appeared to be neutral and held no discernable emotional component, that word was rated at 0 and deleted from the list. If the word appeared to be somewhat positive, such as the word *cute*, then a value of positive 1 was assigned to that word. If the word appeared to be somewhat negative, such as the word *time* used in the negative sense as a drain on time, then that word was assigned a value of negative 1. Similarly, if the word appeared to be highly positive regarding the APA, such as the word *liked*, then that word was assigned a value of positive 2. If a word appeared to be highly negative, such as the word *worthless*, then that word was assigned a value of negative 2.

There were a total of five comments that specifically mentioned the APA. Table 12 lists the comments, while Table 13 depicts the qualitative weighting of key words. As very few comments were available for review, a basic means had been calculated from the weighted values to arrive at an overall measure of how the student felt about the APA in general.

Table 12

APA specific comments from the CHE 103 general survey.

I believe that the early examples provided (not the robot examples) were a little more helpful.

take the mascot, it's worthless, it was better with the examples, but the mascot does not explain anything useful.

I really like the characters when they talk. They are really cute. :)

I wasn't too enthusiastic about the characters we had to choose for the quizzes. While the characters were cute, they didn't do much for my learning experience. All my character did was read what the example said and nothing more. This made my quizzes take a bit longer because the written example would not show up until the character stopped, or was almost finished talking. If the character would work through the problem, or say more than just the upper general description, I would like to see more of him. If not, I don't really need him.

With the worked examples get rid of that darn alien I find it more annoying than helpful please just replace it with a video of a professor going through a similar problem step by step this will help to reinforce what we have learned and help for future in class quizzes and exams.

Table 13

Comments weighted from the end of course survey.

Word or Phrase	Value
helpful	-1
worthless	-2
not explain	-1
liked	+2
cute	+1
wasn't too enthusiastic	-1
cute	+1
didn't do much for my learning experience	-2
take a bit longer	-1
darn	-2
annoying	-1

The mean for the weighted word values for the five comments resulted in a -

.636. Therefore, overall view of the APA from the end of course survey

comments was slightly negative. It should be noted that only comments that

specifically mentioned the APA were utilized in this study.

Possible Confounds

The possibility exists that one APA may be more or less appealing than the

other APAs to the students. If this is the case, chemistry performance and

perception of the APA may be influenced by this factor, which may confound this

study. To determine if this is the case, the choices of the SSA group can be

charted. Of the 35 initial choices made by the students in the self-selected APA

group, eight students chose to study with Pigster, 20 students chose to study

with Pingo, and seven students chose to study with Robo, as shown in Table 14.

Table 14

Frequency statistics for APA choice by the SSA group.

APAname	Frequency	Percent
Pigster	4	27
Pingo	9	60
Robo	2	13
Total	15	100.0

Pingo was selected more than twice as often as the other APAs as the APA

to study with. Therefore, a one-way ANOVA was performed on the AA group to

see if there was a significant difference in perception of the APA's persona

depending upon the APA assigned. The ANOVA revealed no significant

differences based on APA assigned. In fact, perception of Pingo's persona rated

lowest ($M = 2.28$, $SD = .88$) in the analysis ($F(2,27) = 1.342$, $p > .05$), even

though Pingo was chosen most often. Robo scored highest in persona ($M = 2.90$,

$SD = .55$), and Pigster scored in the middle ($M = 2.28$, $SD = .91$). Which APA the

student studied with did not make a significant difference to student perception of

the APA's persona, so it is unlikely that the issue of one APA being preferable to

study with has become a confound in this study. The ANOVA revealed no

significant difference regarding choice of APA on chemistry performance ($F(2,29)$ = 1.342, p > .05)

Another possible confound may have been with the new learner-agent relationship subscale added to the API survey. To test if the new subscale is consistent with the subscales established by Balyor and Ryu for the API (2005), it is appropriate to compare the new learner-agent relationship subscale with the established items in the human-like and engaging subscales. In this case, a T-test compared the new subscale to the established subscales in order to determine if there is any significant difference between these subscales. The T-test revealed that the students rating of items on the new learner-agent relationship subscale (M = 2.39, SD = .42) were not significantly different from the item scores from the established human-like and engaging subscales (M = 2.48, SD = .18, t(18) = -.592, p = .561).

Results Summary

The APA condition assigned consists of no agent, the assigned APA, or the self-selected APA. A summary of results revealed no significant difference between students who studied with an APA and students who did not study with an APA on chemistry achievement as measured by the quizzes. There was also no significant difference apparent in chemistry performance between students who studied with a self-selected APA and students who studied with an assigned APA. On each of the four quizzes, the AA and SSA groups outperformed the NA group with the exception of the first quiz. There was no significant difference apparent on perception of APA as a persona as measured by the API between

students who studied with a self-selected an APA and students who studied with an assigned APA.

However, the APA the student studied with made a significant difference on four of the items on the API. These items stated, "Did you name your agent", "Do you learn more when learning with your agent", "The agent was motivating", and "The agent was expressive". Student who studied with Pingo scored significantly lower on each of these items, differing significantly from Pigster and Robo on the first item, and differing significantly from Robo on each of the four items. Pingo was chosen more often than any other APA, but Pingo scored lowest in student perception of APA persona according to the API. Of all the items in the API, the only item that scored over the neutral rating of three was question 10, which read, "Would you like to be able to customize your agent".

Negative comments from the chemistry 103 general survey that mentioned the APA included negative expressions such as; not helpful, annoying, darn, and worthless. The positive comments regarding the APA were; liked and cute. Overall, there was a slightly negative impression of the APA as reported by comments in the chemistry 103 general survey.

CHAPTER 5

DISCUSSION

Review

The design of this study led to three research questions regarding learning with an APA. An APA is "a computerized character (either human or otherwise), designed to facilitate learning" (Craig, Gholson & Driscoll, 2002, p. 428). The first question asked whether or not interacting with an APA would affect chemistry achievement. Chemistry achievement is measured by the student's chemistry scores on weekly, multiple-choice quizzes. The second question asked whether or not self-selecting an APA to study with affected chemistry achievement. The third question asked whether self-selecting an APA to study with affected the student's perception of the APA as a persona, and questioned their perception of the APA in general. Perception of the APA as a persona is defined as how the students perceive and relate to the APA in learner-agent relationship, human-like, and engaging subscales, as measured through the modified agent persona instrument (API) initially developed by Baylor and Ryu (2005). To answer these questions, this study used a quantitative, quasi-experimental design with repeated measures. An end of the course survey regarding student views on the chemistry 103 course was analyzed using a qualitative approach when these comments pertained to the APA.

The design of this study employed both the cognitive theory of multimedia learning (CTML) for the layout and timing of the learning environment and social agency theory to design the interaction between the student and the APA. The learning environment and presentation of the APA was designed in accordance with CLT (Sweller, 1994) and CTML (Mayer, 2005).

The basic tenants of CLT are that there are dual channels, that processing capacity is limited, and that learning is active. CLT introduced the concept that there is a cognitive processing cost for each element that is presented. CTML built upon these CLT concepts, and CTML has been drawn from many existing theories (Mayer, 2005). Cognitive load theory is a core component of CTML. CTML specifically applies these tenants to multimedia. Because of its multimedia emphasis, CTML is an effective framework to apply when designing an APA presentation.

Social theory regarding the APA developed to accommodate the finding that motivation and enjoyment increased when learning with an APA (Lester et. al., 1997). Social agency theory states that interacting with an APA brings about the learner's social views and expectations of that interaction (Dunsworth & Atkinson, 2007). The learner views the APA as more of an entity rather than a component of the program (Nass & Moon, 2000). The persona effect is the concept that the presence of the APA can directly affect the learner's view of the educational experience. The persona effect implies that the learner views the APA as having certain personality characteristics, and the persona effect is noted when the APA can influence the learner's view on learning (Lester et. al., 1997). Suggestions to

make the APA appear more believable support both the persona effect and social agency theory (Lester, Voerman, Towns, & Callaway, 1999; Nass, Isbister & Lee, 2001).

Based on guidelines suggested by CTML, the presentation of speech appears to be influenced by the presence of the APA (Atkinson, 2002). The APA influences the learner's emotion, motivation and emotion (Moreno, Mayer, Spires & Lester, 2001). Also, the ability to choose which APA to study with has been shown to affect learning (Moreno, Flowerday & Frechette, 2005).

Both CTML and social agency theory are applicable when designing APA presentations. Therefore, both were utilized in this study in order to maximize the educational potential of the learning environment. The design and presentation of the APAs created for this study also relied on the guidelines of both CTML and social agency theory.

Significant Findings

The interesting results of this study do not lie with differences sought between the groups. The condition, whether no APA, assigned APA or self-selected APA, did not seem to make a significant difference in this study. What made a difference was the APA itself, whether selected or assigned, and the comments of the students.

For each of the three research questions investigated in this study, no significant differences were found between the conditions being compared. This means that no significant difference was found in chemistry performance between students who studied with an APA compared to students who did not

study with an APA. No significant difference was found in performance between students who selected their own APA to study with compared to students who were assigned an APA. No significant difference was found in student perception of the APA as a persona between students who selected their own APA to study with compared to students who were assigned an APA.

The APAs were carefully constructed according to cognitive load theory (CLT), the cognitive theory of multimedia learning (CTML) and social agency theory. Presentation of the APA, the worked example window with the worked example and the self-explanation prompt were built in accordance with these theories. What is surprising is that the students did not react to the APAs in the way expected according to prior research.

Although the students should have performed better when studying with an APA (Atkinson, 2002), and should have enjoyed studying with their APA (Lester et al., 1997; Atkinson, 2002), the results of this study did not reveal this. Students who studied with an APA did not significantly outperform students who did not study with an APA.

The Lester study involved 100 middle school students, and received very positive responses from the students. "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" (Lester et al., 1997, p. 364) Also from the Lester study, "The study revealed that well crafted lifelike agents have an exceptionally

positive impact on students. Students perceived the agents as being very helpful, credible, and entertaining" (Lester et al., 1997, p. 365).

However, this study did not match these results, where students did not rate the APA highly on Persona according to the API, and the majority of comments in the chemistry 103 general survey did not welcome the presence of the APA. This was confirmed when key words from the comments were weighed in a qualitative analysis, resulting in a slightly negative view of the APA.

The Atkinson study took place with college undergraduate students, 9 men and 51 women. Regarding studying with an APA which used voice and gesture in the Atkinson study, "it is apparent from the evidence compiled in the present study that learners who are engaged in mathematical thinking can benefit on a variety of cognitive and affective measures by working within a learning environment that contains an animated pedagogical agent," (Atkinson, 2002, p. 426). Again, the academic benefits of studying with an APA were not supported by this study.

Another example of conflicting results is the finding that choice made no difference in this study, either in chemistry performance or in student perception of the persona of the APA. This may be due in part to the fact that prior research regarding student choice of APA used race and gender specific APAs (Moreno, Flowerday & Frechette, 2005) while this study did not. The student comment requesting a video of the professor seems to emphasize that students prefer to learn with a human instructor, or possibly an animated image of a human instructor rather than an APA. It is conceivable that students may view studying

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with an APA as less effective than studying with a human or human-like instructor, or video of a human instructor. It may be that in more human-like APAs, or APAs that score more highly on the API, student performance may be significantly affected by choice.

One possible interpretation may be that there is an initial novelty effect when students study with an APA, and that this benefit is lost over time such as in a multiple measures study. Most APA research is not conducted over time, but over one or two sessions at most. This includes all of the research cited in this study. Therefore a novelty effect may be present in prior research. If a novelty effect of studying with an APA can account for improved performance or perception of the persona of the APA, then the resources required to produce and maintain an APA over the period of an entire course may not be cost effective. If future research supports this supposition, then the APA should be reserved for critical, single session presentations rather than a continuous appearance throughout a course.

The results in this study obtained from follow-up tests showed significant differences in one particular APA, Pingo, on 4 items of 20 in the API. Pingo scored significantly lower than the other two APAs on perception of persona in these questions, although Pingo was the APA chosen most often by a large margin. If the number of subjects had been larger, the results may have revealed a significant preference for Pingo as the APA of choice.

It may be possible that Pingo was chosen more often due to the APA's appearance. Although the results were not significant, Pingo was chosen twice

as often as the other APAs, and may be seen as more visually appealing than the others APAs. If this is the case, the comments from the chemistry 103 general survey may help to understand why this APA has such a low rating of persona despite being the most popular APA, and why the students did not respond to the APA according to prior research. In fact, the APAs were rated somewhat negatively overall.

Comments from the chemistry 103 general survey that mentioned the APA included negative expressions such as; not helpful, annoying, darn, and worthless. The positive comments regarding the APA were; liked and cute. It may be possible that the students see the APA as something different than an educational assistant, and tend to focus on the visual and aesthetic appeal of the APA, as apparent in the words, liked and cute.

If this is the case, if the APA is effectively window dressing, then the positive response of students to APAs in prior studies may be interpreted as a novelty effect, similar to decorating the computer screen. In support of this is the fact that the only item to score over the neutral score of 3 in the API asked, "Would you like to be able to customize your agent". This would support the concept that the students tend to view the APA as a functional decoration, and respond most favorably when the APA is viewed in this regard. Though the APA may be viewed as decoration, this does not imply that the APA is not viewed as an instructor, study partner or learning tool, but raises the possibility that the visual and aesthetic appeal of the APA may be a priority among students.

Visual appeal of the APA appears to be a factor in student selection of the APA, and may influence their expectations of their experience with that APA. This study applied race and gender neutral APAs over multiple measures in an environment that supported CLT, CTML and social agency theory. Therefore, a unique opportunity was available to gauge student responses to the APA.

Theoretical and Educational Implications

As no significant difference was found in chemistry performance between the assigned groups, it would appear that studying with an APA does not impact learning. Certain studies have shown a positive increase in academic performance when studying with an APA (Atkinson, 2002), however, the results are inconclusive (Clark & Choi, 2005). Although more research is needed, the results of this study would suggest that the use of an APA to enhance learning and performance is not an effective practice.

One possible exception to this generalization lies with the age of the students. Studies with younger subjects such as middle school students tended to show an increase in performance, whereas this study involving undergraduate college students did not show a significant increase in chemistry performance (Atkinson, 2002).

The presence of an APA is not sufficient to create a strong positive perception of APA persona, as reflected by the low scores from the Agent Persona Inventory (API). It should be noted that the results of this study can only be generalized to college undergraduate chemistry students. This implies that attempts at creating persona in the APA with undergraduate learners may meet with minimal success.

However, with a younger audience, the perception of APA persona and the corresponding benefits of motivation and enjoyment may be significant (Nass, Isbister, Lee 2001; Lester et al., 1997; Atkinson, 2002).

This study indicates that college aged learners realize minimal benefits, if any, from the presence of the APA, even over a series of several weeks. This applies to both chemistry performance and perception of APA persona, where younger learners often experienced significant results in both areas. Therefore, as prior research implies, APAs should be utilized when the subjects are younger learners.

Choice did not appear to negatively impact learning, as chemistry performance when studying with an APA was not significantly affected in this study. In a prior study where subjects chose the gender and race of the APA (Moreno, Flowerday & Frechette, 2005), there was a significant negative impact in student performance. This study used race and gender neutral APAs and did not experience these negative results. In keeping with prior research and the results of this study, choice of APA regarding selection of race and gender should not be an option until the impact of APA race and gender on student learning can be predicted.

This study delivered the complete APA presentation online over a period of several weeks. The APA was presented onscreen when an example button was pressed, opening a window containing the APA. The APAs were fully animated characters complete with voice. The delivery format was in Flash, presented as a 2D learning environment. The programming was done in a variety of

programming languages, but delivered on the server computer through php and on the client computer through JavaScript and Flash. Data obtained online during the study was stored in a secure database.

Current technology allows the production of such learning environments, and the average computer user may view such presentations. Further, any unforeseen difficulties or necessary adjustments may be addressed if the presentation is online. If the presentation is on a CD or DVD, then no adjustments can be made after these presentations have been distributed. Therefore, online presentations featuring APAs should be considered as a practical alternative to delivering a presentation via a CD or DVD. Unless extremely large, complex, interactive 3D immersive environments are presented, online presentations should be considered as the standard means of content delivery, as utilized in this study.

What did make a difference to the learner in this study was the specific APA the learner was paired with, as perception of APA persona varied significantly on certain items of the API. One of the most interesting results was the desire to customize the APA. As appearance of the APA matters to the learner and as choice may have an impact on the learner, then a combination of these would be customization (Gulz & Haake, 2006; Moreno, Flowerday & Frechette, 2005). If the APA is seen as an object or fashion piece that may be customized according to learner preference, then this option should be included at the onset of any presentation that includes the use of an APA, which may result in a more positive perception of persona as well as the theoretical benefits.

Limitations

When designing an APA, there are nearly infinite possibilities. Due to the wide variation in design and implementation of an APA, the APAs used in this study would be unlike any other APA from any other study. This rich variation may be a limitation in this study, as another APA used in prior research may have yielded quite different results. It is nearly impossible to create the same APA, the same animation sets, and the same voice sets from study to study, so that accurate replication of an APA without access to the specific model, voice, and animation files used in the initial study would be literally impossible. This could account for some variation from study to study, such as the failure of this study to reveal a strong perception of the persona effect for the APAs.

Keeping the variety of APAs in mind, it is possible that people react to different APAs differently. In this study it was shown that a certain APA may be chosen more often over other APAs as a study partner. While it is unclear from this study whether choice of APA influenced learning, the impact of student preference for APA should be investigated in future research. Unfortunately, a solution to this problem of replication is needed. As replication is currently not possible, any generalization regarding an APA is currently limited, other than within the confines of that specific study and with that particular APA.

This study only allowed one initial choice of APA. The reasons for this varied, and included the problem of reducing the number of subjects in each pool if the group assignments were further divided, and also the difficulty involved in

creating a learning environment which held more choices. Therefore, this study allowed only one initial choice at the very beginning of the study.

Although the Mayer and Flowerday study (2005) allowed choice only initially as well, a study on choice of APA could potentially allow choices to be made throughout the duration of the study. Choices need not be limited to the appearance of the APA, but may include the opportunity to switch one APA for another, and further choices could be made available.

When further choices are made available, this could be called customization. Customization of the APA could happen initially, where the learner chooses various aspects of the APA such as height, color of skin, hair, eyes, and so forth, the voice of the APA, and any accessories such as a cane, hat, cloak, shirt, pants, or shoes. Customization could also happen as the game or venture continues, where the animated character changes appearance or accessories according to the desire of the learner.

These choices are available in a variety of computer games and online ventures, such as the Wii gaming system and Gaia online, where the game player designs the character initially and may customize the character as the game or venture goes on. As these options are common in gaming, perhaps they could be adapted to the learning environment and should be investigated in APAs as well. There seems to be an interest in customizing an APA, and the results of this study indicated that certain expectations arise when choice is exercised regarding an APA. Unfortunately, the scope of this study did not allow for customization.

Another limitation in APA research is the comparison of the technology apparent in the agent, between academic interests and commercial markets. An APA is an animated teaching agent, yet many other kinds of animated agents exist. The APA used in academic studies is less likely to be as fully developed as an agent used in the computer gaming industry. Where academics have notoriously limited funding, commercial ventures may spend millions developing animated characters, human or otherwise, to increase the realism and persona of that animated character.

One example is the level of development of the APA used in this study when compared to various commercial ventures. The APAs in this study were crafted by one individual, whereas a character developed for television may have a complete team working on that character's development. The programming in this study was also completed by one individual, where a full team of programmers may work for many months to develop the game characters for a single game. This study had no budget at all. This difference in development is apparent when academic computer games and ventures are compared to commercial computer games and ventures.

Research states to make the APA as realistic as possible (Lester et. al, 1997; Gulz & Haake, 2006). The appearance of the APA does influence the learner's cognitive assessments (Lee, Isbister & Nass, 2000). When exposed to an APA, it may be that the level of realism does not match that of the animated character backed by a commercial venture.

Because of this discrepancy, the average individual may expect a more polished APA than the one presented in academic research. If such is the case, then the perception of persona may be rated quite low comparatively due to the influx of more fully developed animated characters that the individual may encounter on a daily basis. Therefore, it is difficult to generalize the results of current APA research to any situation out of the academic setting. When comparing perception of persona between an APA and an animated character driven by a commercial venture, the responses of the learner may vary greatly between the two.

Another limitation in this study was the low rate of response regarding the APAs in the end of semester general survey. Although any response that mentioned an APA was qualitatively analyzed, the low number of responses did not build reliability. Rather than specific responses to a general survey, more targeted questions specifically mentioning the APA could have been included in order to raise the pertinent number of responses.

Another suggestion would be to implement an exit interview, specifically asking about the learner's experience when learning with an APA. This format could allow open ended answers, which could reveal more information from a qualitative analysis than the few answers provided in this study. One of the limitations with this suggestion would be the time investment required in the analysis, although the benefits could be substantial.

Contributions

The APA the student learned with made a significant difference in many ways. This study has shown that the desire to customize an APA can vary depending upon the APA used, and even the APA chosen. If the learner chose the APA, then customization of that APA is less desirable as the learner has already been able to exercise some level of customization over that APA. If the learner did not get to choose the APA, then the learner wished to customize that APA. Therefore, it is apparent in this study that the need to exercise some choice regarding the presentation of the APA, whether initially or during the interaction with the APA, has a significant impact on the learner.

This study also illuminated the concept of customization when applied to an APA. If the appearance of the APA does influence the learner, then customization of the APA may result in a greater perception of the persona of that APA, which may lead to better performance and enjoyment for the learner (Lester et. al., 1997; Atkinson, 2002). The difficulty with customization is that it is complex to design, program and implement, however the potential benefits are substantial.

This study was one of the first to conduct APA research over a significant period of time, with data collected each week for four quiz trials after an initial pilot study to test and establish the necessary functionality and conformity to CTML and social agency theory. It may simply be that using an APA over time does not make a difference in student learning. Although no significant performance improvement was found in this study in the chemistry domain with this university student population, performance when studying with an APA was

better on three out of four quiz trials, and if the study had continued may have been found to be significant. Similarly, the effects of choice of APA were minimal regarding chemistry performance and revealed no significant results. However, this study may be one of the first to assess the effects of student choice of APA as well as student performance when studying with an APA over time.

While a study of choice has been conducted, this study is one of the first to conduct choice studies with racial and gender neutral APAs. It appears that while certain APAs may be preferable, there may also be certain expectations that students associate with that choice. The APA appears to be viewed as a kind of decoration, as well as a teacher or study partner. The duration of this study allowed for this concept of duality to be explored.

Future Research

It is suggested that, as commercial ventures regarding animated character are more heavily funded and the results are often superior to the APA used in research, researchers could attempt to secure various commercial animated characters for use as an APA in a learning environment. Commercial companies often donate to educational facilities both financially and technologically, such as donating computers or software. If the commercial company could donate an animated character which already held the interest, and possibly high persona rating of the learner, then that character as an APA may make a significant impact in research.

For example, Snow White of Disney fame could be utilized by the researcher as an APA in a program to teach students cooking. Although certain educational

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games exist where the character is a well known commercial product, no APA research is being conducted which utilizes these well known, well crafted APAs. If well made, popular APAs could be secured or licensed for use, the ease of setting up APA research, as well as the quality of that research, would improve dramatically.

This is supposition, but could be easily verified by testing student performance and perception of APA using a well known, well crafted commercial animated character in a study. If the learners using the commercial characters outperform the research institution APAs, then the reasons may be either a higher persona rating from prior knowledge, or that the character is exceptionally well crafted and functions well as an APA. Both reasons are viable, and potentially applicable to a host of educational uses.

In order to standardize APA research and to enable APA research to be replicated, there should be an online depository to contain all of the files used in a particular study. These files would include the model for any APA used in the study, as well as the animation files, the voice files, the presentation files pertaining to the learning environment, and any other programming files necessary, as well as noting any of the software required to enable it's implication, such as the 3D software program used to design and build the APA, and the 2D presentation software. For example, this study used Lightwave to create and design the 3D models, Flash for their presentation as animation files, files programmed in Actionscript, Javascript, PHP and MySQL, and various MP3 voice files.

If these files were available to researchers, then replicating a certain study would be possible. Without access to such files, no APA research could be accurately replicated. APA studies involve far more than questionnaires. The environment in which the learners study is heavily manipulated and quite complex. It is suggested that the journal that publishes the academic paper be responsible for hosting the files relating to the study as well, if the files are to be released to the academic world for possible replication of the study.

Another use of the internet would involve the research itself. Rather than have the study limited to one university classroom, which is often the case, a study should be able to span several universities or academic settings, potentially around the world.

For example, this study involved one entry level chemistry class. Exposure to an APA was provided online. Information was stored in a robust, well programmed database with safeguards built in. Animation files were stored on a reliable server. Using an effective delivery system such as this, many entry-level chemistry classes could be included in the same study at once, regardless of location. By increasing the number of students and by generalizing the subject population, the results have the potential to be more robust.

Using modern computer techniques, a quantitative analysis such as an ANOVA is only slightly more complex when studying several hundred, or even several thousand students. The benefits of such an increase in subject population, however, may be quite substantial.

APPENDIX A - COPY OF INFORMED CONSENT FORM

Student Use of Web-based Materials in Undergraduate Chemistry

Informed Consent Form

OPRS#-0505-1589

Purpose of the Research

We are interested in the effect of motivation on student use of Web-based course materials and its impact on performance.

Procedures

Your instructor will be using *WebCT* to provide additional learning materials as part of this course (e.g., lecture notes, additional readings, examination answers, on-line assessments/worked examples). You have the option of using these materials to improve your performance in the course. We seek permission to track your use of the Web-based materials and to use your exam scores. In addition, we request that you complete a few surveys.

Data collection will involve use of the Web through integration with *WebCT*. Accepting participation in this study allows us to use your data in our study. Declining participation means we cannot use your data in our study, but **does not** affect your access to materials. Your participation is strictly voluntary.

Pressing the 'Accept' button constitutes informed consent and includes your data in the study. Selecting 'Decline' allows access to the materials but does not include your data in our study.

Data from this study will be stored on a Web server located in a secure location on the campus at the University of Nevada Las Vegas (UNLV). Records will be removed from the server for analysis at the end of the current academic term. Records will be destroyed following analysis.

Student identity is anonymous. Your L-number and login will solely identify you during data collection. At the completion of data collection, the results of the assessments will be removed and compiled. A random anonymous coding system will be applied before data analysis.

Risks

Risk to participants is minimal. Access to the site is password restricted and the data is stored securely on campus. Complete security of any computer system can never be guaranteed, but every reasonable effort will be made in this regard.

Benefits

Participants who use the Web-based course materials to learn chemistry may gain a deeper understanding and improve their performance.

Confidentiality

The privacy of participants will be maintained throughout the study. We cannot guarantee the confidentiality of this information because it is gathered using the Web and Web-access to the database by surreptitious means unknown to us may be possible now or may become possible in the future, however.

Compensation

There is no compensation for participating in this research.

Opportunity to Ask Questions

Persons interested in discussing the research can contact the principal investigator, Dr. Kent J. Crippen, kcrippen@unlv.Nevada.edu, (702) 895-2517.

Freedom to Withdraw

You are free to decide not to participate in this study or to withdraw at any time without adversely affecting your relationship with the investigators, the University of Nevada-Las Vegas, or the participating agent. Your decision will not result in any loss of benefits to which you are otherwise entitled.

Consent, Right to Receive a Copy

You are voluntarily making a decision whether or not to participate in this research study. 'Accepting participation' certifies that you are **at least 18 years of age** and have decided to participate. By "clicking" on the 'Accept' button, you are acknowledging you meet the minimum age requirement and agree to participate.

We encourage you to print a copy of this form for your records.

Investigators

Dr. Kent J. Crippen, kcrippen@unlv.Nevada.edu, (702) 895-2517.
Dr. MaryKay Orgill, MaryKay.Orgill@ccmail.nevada.edu, (702) 895-3580.

IRB Contact

For questions regarding the rights of research subjects, please call the UNLV
Office for the Protection of Research Subjects, (702) 895-2794.

APPENDIX B – MODIFIED AGENT PERSONA INSTRUMENT

Learner-Agent Relationship (10 item)

Did you name your agent?
Did you talk to your agent?
Do you learn more when learning with your agent?
Do you like learning with your agent?
Would you like to see your agent again in another class?
Would you like your agent to remember you?
Would you like to receive an email from your agent?
Would you like to continue working with your agent for the rest of this course?
Do you and your agent make a good team?
Would you like to be able to customize your agent?

Human-like (5 items)

The agent has a personality.
The agent's emotion was natural.
The agent was life-like.
The agent's movement was natural.
The agent showed emotion.

Engaging (5 Items)

The agent was expressive.
The agent was enthusiastic.
The agent was entertaining.
The agent was motivating.
The agent was friendly.

APPENDIX C – END OF COURSE SURVEY QUESTIONS

Questions

If you used the worked examples and felt they were helpful, please provide a description of a situation where the worked examples were most helpful.

If you used the worked examples, rate their effectiveness in improving your overall performance in chemistry 103.

The quizzes in chemistry 103 are intended to be learning opportunities. That's why, for instance, you have the option of changing your quiz answers throughout the week. If you consider the current quiz structure, the worked examples, and the solution suggestions: what other things could we add, or changes could we make that would help you be successful in chemistry 103?

REFERENCES

Andre, E. (1999). Special Issue: Animated Interface Agents: Making Them

Intelligent. *Applied Artificial Intelligence, an International Journal* 13(4-5),

341-565.

Astleitner, H., & Wiesner, C. (2004). An integrated model of multimedia learning

and motivation. *Journal of Educational Multimedia and Hypermedia*, 13(1),

3-21.

Atkinson, R. K. (2002). Optimizing learning from examples using animated

pedagogical agents. *Journal of Educational Psychology*, 94(2), 416-427.

Atkinson, R.K., Mayer R.E., & Merrill M.M. (2005). Fostering social agency in

multimedia learning: Examining the impact of an animated agent's voice.

Contemporary Educational Psychology, 30(1), 117-139.

Baddeley, A., & Andrade, J. (2000). Working memory and the vividness of

imagery. *Journal of Experimental Psychology*, 129(1), 126–145.

Baddeley, A., Gathercole, S., & Papagno, C. (1998). The phonological loop as a

language learning device. *Psychological Review*, 105(1), 158–173.

Baylor, A., & Ryu, J. (2003). The effects of image and animation in enhancing

pedagogical agent persona. *Journal of Educational Computing Research*,

28(4).

Burleson, W., Picard R.W. (2004). Affective Agents: Sustaining Motivation to

Learn Through Failure and a State of Stuck. *Social and Emotional*

Intelligence in Learning Environments Workshop In conjunction with the

7th Intl. Conf. on Intelligent Tutoring Systems, August 31st, 2004

Clark, R. (1983). Reconsidering research on learning from media. *Review of Educational Research*, 53(4), 445-459.

Clark, R., & Choi, S. (2005) Five Design Principles for Experiments on the Effects of Animated Pedagogical Agents. *Journal of Educational Computing Research*, 32(3), 209-225.

Craig, S., Gholson, B., & Driscoll, D. (2002) Animated Pedagogical Agents in Multimedia Educational Environments : Effects of Agent Properties, Picture Features, and Redundancy. *Journal of Educational Psychology*, 94(2), 428-434.

Crippen, K J., Earl, B. L. (2007) The Impact of Web-based Worked Examples and Self-Explanation on Performance, Problem Solving, and Self-Efficacy *Computers and Education,* 49, 809 - 821.

Dunsworth, Q., Atkinson, R K. (2007) Fostering Multimedia Learning of Science: Exploring the Role of an Animated Agent's Image, *Computers and Education*, 49, 677 – 670.

Gratch, J., Rickel, J., André, E., Cassell, J., Petajan, E., & Badler, N. (2002). Creating Interactive Virtual Humans: Some Assembly Required. *IEEE Intelligent Systems*, July/August, 54-61.

Gulz, A., Haake, M. (2006). Design of animated pedagogical agents - A look at their look. *International Journal of Man-Machine Studies* 64(4): 322-339 (2006)

Hone, K. (2005) *Animated agents to reduce user frustration.* Paper presented at

the 19th British HCI Group Annual Conference, Edinburg, UK

Honebein, P. C. (1996). Seven goals for the design of constructivist learning

environments. In B. Wilson (Ed.), *Constructivist learning environments.*

Englewood Cliffs, NJ: Educational Technology pp. 11-24

Kalyuga, S., Ayres, P., Chandler, P., Sweller, J. (2003). The Expertise Reversal

Effect. *Educational Psychologist* 38 (1), 23 – 31

Keppel, G. (1973) *Design and Analysis. A Researcher's Handbook.* Upper

Saddle River, N.J.: Prentice Hall, 1973.

Lester, J. C., Converse, S. A., Kahler, S. E., Barlow, S. T., Stone, B. A., & Bhogal,

R. S. (1997). The persona effect: affective impact of animated pedagogical

agents, *Proceedings of the SIGCHI conference on Human factors in*

computing systems, 359-366, Atlanta, Georgia, United States

Lester, J. C., Voerman, J. L., Towns, S. G., & Callaway, C. B. (1999). Deictic

believability: coordinated gesture, locomotion and speech in lifelike

pedagogical agents. *Applied Artificial Intelligence,* 13(4-5), 383-414.

Levy, L.M., Henkin, R.I., Lin, C.S., Hutter, A., and Schellinger, D. (1999) Odor

memory induces brain activation as measured by functional MRI. *Journal*

of Computer Assisted Tomograhy 23, 487-498

Mayer, R. E. (2001). *Multimedia learning.* Cambridge, UK: Cambridge University

Press.

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in

multimedia learning. *Educational Psychologist,* 38(1), 43-53.

Mayer, R. E. (Ed.) (2005) The Cambridge Handbook of Multimedia Learning, Cambridge (MA), Cambridge University Press.

McLaughlin, M. L., Rizzo, A., Jung, Y., Peng, W., Yeh, S-C., & Zhu, W. (2005). Haptics-enhanced virtual environments for stroke rehabilitation. Proc. IPSI 2005, Cambridge, MA

Miller, G. A. (1956) The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review* (63), 81 - 97

Moundridou, M. & Virvou, M. (2002) Evaluating the persona effect of an interface agent in a tutoring system. *Journal of Computer Assisted Learning* 18(3): 253-261

Moreno, R. (2005). Multimedia learning with animated pedagogical agents. In R. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (pp. 507-524). New York: Cambridge University Press

Moreno, R., Flowerday, T., & Frechette, C. (2005, April). Does the Choice of Animated Pedagogical Agents Help Students Learn Science from a Multimedia Game? Paper to be presented at the 2005 annual meeting of the American Educational Research Association (AERA), Montreal, Canada

Moreno, R., Mayer, R., Spires, & Lester, J. (2001). The Case for Social Agency in Computer-Based Teaching: Do Students Learn More Deeply When They Interact With Animated Pedagogical Agents? *Cognition and Instruction*, 19(2), 177-213

Nass, C., Isbister, K., Lee, E., (2001). Truth is beauty: researching embodied

conversational agents. *Embodied conversational agents*, MIT Press,

Cambridge, MA

Nass, C. & Moon, Y. (2000). Machines and mindlessness: Social responses to

computers. *Journal of Social Issues*, 56(1), 81-103.

Pavio, A. (1969). Mental imagery in associative learning and memory.

Psychological Review, 76, 241–263.

Penney, C. (1989) Modality Effects and the Structure of Short-term Verbal

Memory. *Memory and Cognition*. 17: 398-422.

Peterson, L.R., & Peterson, M. (1959). Short-term retention of individual items.

Journal of Experimental Psychology, 58, 193-198.

Reed, S. K. (2006). Cognitive Architectures for Multimedia Learning. *Educational

Psychologist*, 41(2), p. 87-98.

Renkle, A., Atkinson, R. K., & Grobe C. S. (2004) How Fading Worked Solution

Steps Works – A Cognitive Load Perspective *Instructional Science*, 32(1),

59-82.

Ricci, C. M., & Beal, C. R. (2002). The effect of interactive media on children's

story memory. *Journal of Educational Psychology*, 94(1).

Schnotz,W. (2002). Towards an integrated view of learning from text and visual

displays. *Educational Psychology Review*, 14, 101–120.

Schnotz, W., & Bannert, M. (2003). Construction and interference in learning

from multiple representation, *Learning and Instruction*,13, pp. 141-156.

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional

design. *Learning and Instruction* 4, 295-312.

van Merriënboer, J. J. G., Kirschner, P. A., & Kester, L. (2003). Taking the load

off a learner's mind: Instructional design for complex learning. *Educational*

Psychologist, 38, 5–13.

Westelinck, K. D., Valcke, M., de Craene, B. & Kirschner, P. (2005). Multimedia

learning in social sciences: limitations of external graphical

representations. *Computers in Human Behavior*, 21, 555-573.

Yanghee, K., Baylor, A.L. (2006) Pedagogical Agents as Learning Companions:

The Role of Agent Competency and Type of. Interaction *Educational*

Technology Research and Development, 54(3)

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