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Yanghee Kim
Utah State University

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Desirable Characteristics of Learning Companions

Yanghee Kim, *Department of Instructional Technology, Utah State University, 2830 Old Main Hill, Logan, Utah 84322, yanghee.kim@usu.edu, http://www.create.usu.edu*

Abstract. This study investigated the desirable characteristics of anthropomorphized learning-companion agents for college students. First, interviews with six undergraduates explored their concepts of desirable learning companions. The interviews yielded agent competency, agent personality, and interaction control. Next, a controlled experiment examined whether learner competency (strong vs. weak) would relate directly to agent competency (high vs. low) and to interaction control (agent-control vs. learner-control). The dependent measures included learners' perceptions of agent functionality, their self-efficacy beliefs in the task, and their learning. The results indicated that academically strong students perceived the high-competent agent higher than the low-competent agent and showed higher self-efficacy beliefs in the task and recalled more after working with the high-competent agent. Academically weak students, by contrast, showed higher self-efficacy and recalled more after working with the low-competent agent. Also, academically strong students valued agent-control highly, but academically weak students valued learner-control. The strong students showed higher self-efficacy in agent-control but lower self-efficacy in learner-control than did the weak students. In general, the results indicated that the similarities of characteristics between an agent and a learner have positive impacts on learners' cognitive and affective attainments.

Keywords. Learning companions, virtual peers, pedagogical agents, learner characteristics

INTRODUCTION

Pedagogical agents—animated, life-like characters (Johnson, Rickel, & Lester, 2000) in a computer-based learning environment—have recently attracted researchers in educational technology. In this environment, students individually learn instructional topics while interacting with agents designed to effect instructional applications. Specifically, learners can get help messages efficiently in a conversational format that replaces traditional text-based messages (Dempsey & van Eck, 2003), and/or the learners can receive from the agent verbal help messages and encouragement that human instructors in traditional settings are typically expected to provide (Burleson, Picard, Perlin, & Lippincott, 2004; Gulz, 2004; Klein, Moon, & Picard, 2002). Hence, it seems plausible to expect that, while learning with an agent, a learner might be able to build social relations with that agent (Ryokai, Vaucelle, & Cassell, 2003), just as in learner/teacher relations in classroom, and that these kinds of learner/agent relations would facilitate the learner's engagement in the tasks. To increase the likelihood that learners will relate to pedagogical agents, it is often recommended that a pedagogical agent look human-like and display its own persona (Baylor & Kim, 2005; Bickmore, 2003; Laurel, 1990; Mulken, Andre, & Muller, 1998). A variety of human metaphors are employed in designing the personas of effective pedagogical agents, such as "experts" (Johnson, 2001), "tutors" (Graesser, Moreno, & Marineau, 2003), "motivators" (Baylor & Kim, 2005), "coaches" (Seiker, 1994), and "learning companions" (Burleson & Picard, 2004; Kim, 2005).

Given the positive impact of peer interaction in traditional settings, this study focused on pedagogical agents as learning companions (PALs), adopting a peer metaphor in their pedagogical design and implementation. In classrooms, the benefits of peer-to-peer interaction over teacher-to-learner interaction have been well-supported, theoretically and empirically (Bandura,

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1997; Griffin & Griffin, 1998; King, 1998; Matusov & Hayes, 2000; Piaget, 1995; Rowell, 2002; Schunk & Hanson, 1985; Topping *et al.*, 1997; Yarrow & Topping, 2001). In particular, the value of social interaction with equally able peers has been highlighted, given that the cooperation of equal partners fosters intellectual development, thinking, and affect (Matusov & Hayes, 2000; Piaget, 1995). Peer interaction may provide a free and open forum to facilitate the active and productive exchange of ideas (Driscoll, 2000). Acknowledging the benefits of peer interaction, researchers have attempted to simulate this interaction in tutoring systems (Biswas, Schwartz, & Bransford, 2001; Brophy, Biswas, Katzlberger, Bransford, & Schwartz, 1999; Chan & Baskin, 1990; Chou, Chan, & Lin, 2003; Ryokai, Vaucelle, & Cassell, 2003). Earlier uses of learning companions dealt mainly with the technical functions of the tutoring systems, focusing on the systems' learning along with the learners rather than teaching them (Chan & Baskin, 1990). More recently, with the advances of interface technology, anthropomorphized learning companions—"looking peer-like"—have focused attention on the possibility of building social relations with the learner. For instance, the virtual peer *Sam* for pre-school children was designed to look like a pre-schooler and told a story collaboratively with the children in a linguistically advanced manner. The children carefully listened to and assisted Sam by suggesting improvements (Ryokai, Vaucelle, & Cassell, 2003).

The recent trend seems to highlight the potential of supporting social interaction and building social relations between a learner and a learning companion (Bickmore, 2003; Gulz, 2005; Kim & Baylor, in press), which may distinguish pedagogical agents from conventional computer-based approaches. This trend also seems in line with a trend in human/computer interaction research, arguing that people often tend to apply unconsciously the same social expectations and rules to a computer as they do to humans in the real world (Reeves & Nass, 1996). Traditional HCI approaches haven't explored deeply the issue of how to support social interaction and build social relations. Anthropomorphized learning companions may open the possibility for just such deep exploration. Just as the social interaction with the teacher (or peers) and the learner's perceptions of them play important roles in influencing the learner's efficacy beliefs and motivation to learn in the traditional classroom setting (Sutton & Wheatley, 2003), so the social interaction with learning companions and the learner's perceptions of them might influence the learner's cognitive and affective characteristics in computer-based environments.

The current study was thus guided by the question of how to design pedagogical agents as learning companions (PALs) to facilitate social relations with a learner and to enhance the learner's perceptions of the PALs. The study, conducted in two phases, attempted to learn which key characteristics of PALs would influence the perceptions, motivation, and learning of college students. Anthropomorphized PALs are an emerging technology, and very few studies have examined what characteristics would increase their appeal to the learners. In the first phase, the author took the perspective of grounded theory (Patton, 2002), by which she explored to find answers through listening to college students, without a priori assumptions. In-depth qualitative interviews were conducted to answer the question, *What are undergraduate learners' expectations of the desirable characteristics of their PAL*? Individual interviews yielded three desirable PAL characteristics: agent competency, agent personality, and interaction control. In the second phase, a controlled experiment was conducted to answer the question *How does learner competency interact with agent competency and with interaction control?* Detailed explanations of each phase of the study follow.

PHASE ONE: EXPLORATORY INTERVIEWS

The author inquired into learners' expectations from the constructivist view that learners are active meaning-makers of their environments, bringing their own perspectives and expectations to the learning contexts. Their expectations may influence their engagement in the task to varying degrees. Drawing on Persson and colleagues (2002), who emphasized learners' perspectives in understanding and interpreting agent systems in the perspective of socially intelligent agents, the author concluded that to facilitate social relations with learners, PALs may need to be designed to be compatible with learners' expectations and that the learners' expectations about their desirable PAL should matter in designing PALs able to build social bonds with the learners. Another issue in this phase was whether a learner's expectations of a PAL were consistent with his or her expectations of human partners. This topic has been visited frequently in the studies on human/computer interaction by Nass and colleagues (Isbister & Nass, 2000; Nass, Fogg, & Moon, 1995, 1996), but not directly addressed in the context of anthropomorphized learning companions in instructional environments. Those studies revealed that users unconsciously applied social rules to computers; however, it is unknown whether learners' expectations of their virtual-learning partners would be consistent with their expectations of good human-learning partners. Two specific questions informed Phase One: 1) *what characteristics of a PAL do learners consider important?* 2) *Are learners' expectations of a PAL consistent with their expectations of a human partner?*

Participants

Participants were six pre-service teachers who took an introductory educational technology class in a large southeastern U.S. public university. Convenience sampling was adopted, for two reasons: first, it was considered that pre-service teachers in general had more opportunities to think about the issues and dynamics of teaching and learning; second, the participants were voluntarily drawn from the class the author was teaching because their coursework had given them experience in an agent-based learning environment. This environment included two types of pedagogical agents, Expert and Motivator (Baylor & Kim, 2005). The Expert agent, designed to represent a man in his forties, provided accurate information in an authoritative voice and was emotionally detached from the learners. The Motivator agent, in his twenties, was presented as not particularly knowledgeable but as an eager participant who suggested his own ideas and verbally encouraged the learner to sustain at the tasks. Three male and three female participants volunteered to be interviewed in the study. The average age of the participants was 19.48 (SD=1.64); four of the participants identified themselves as Caucasian and two as Hispanic-Caucasian.

Data Gathering

In-depth semi-structured interviews were conducted by the author. A questionnaire with five questions was prepared: 1) *Tell me your experience with the on-screen characters in the instructional applications*, 2) *What did you like most about them?* 3) *What did you like least about them?* 4) *How would you design a virtual character to positively affect your motivation and learning in computer-based environments?* 5) *What characteristics of a computerized virtual peer are most important to you?* The researcher used the questions flexibly, allowing learners to express freely their own ideas on the matter. The interviews, taking two days, were conducted right after completion of the course. On the first day, with three participants, the author identified some overlap in their answers to the questions. So the wording of the questions was modified slightly, without changing the original questions qualitatively. On the second day, the other three participants were interviewed. The participants voluntarily chose the interview day, based on their convenience. The interviews were tape-recorded (with the permission of the interviewees) and later transcribed. Each interview took approximately forty minutes, with individual variations.

Emerging Themes

Competency

Answering the five questions, all the interviewees consistently mentioned task-related information or knowledge as the major feature they expected from a PAL assisting their learning. The participants said that they would appreciate motivational input from a PAL but that obtaining information or advice from the PAL should be most important. In particular, a participant who had experience in working with a motivator agent designed to provide only persuasive encouragement (Baylor & Kim, 2005) expressed her discomfort: "Positive if he has [ideas to present]. Negative if he does just cheerleading when I am self-motivated." The author named this category *competency*, a term used in previous agent research (Hietala & Niemirepo, 1998; Kim & Baylor, in press).

Personality (or Persona)

The participants used several personality-related adjectives to describe the characteristics of a PAL they would like to work with: *friendly, motivating, encouraging, comfortable, positive, energetic, nice*, etc. In a prior class, the participants had worked with an expert-like agent who was designed to provide information in an authoritative manner (Baylor & Kim, 2005). They subsequently commented on their interactions with this agent: "He was just straight to give information. Make it more comfortable. . . Interactive." "He should try to help and try to motivate you. He [should] be encouraging." Interestingly, all the female participants put an emphasis on the personality aspect of agents, by listing more adjectives (characteristics) and by using more animation in their voice; only one male student brought up the personality adjectives.

Interaction Control

The interviewees cited the issue of interaction control (the author's term) as important in a PAL-based learning environment. Interaction control indicates who initiates the interactions, the PAL or the learner. The participants expressed contrasting ideas evenly on this issue. Three participants expected a PAL to initiate their interactions by providing proactive guidance: "[He] need[s] to guide me." "[I] want him to take a lead [in doing the task]." The other three preferred to control the interaction themselves: "I still want to take a lead, probably. He still remains responsive." "[The agents] kept popping up when I didn't want them to because I was trying to read and they would come up and say . . . You can't control them. . . It was good, but if you could just have more control over them . . ."

Consistency of Learner Expectations

Another issue of interest was whether a learner's expectations of a PAL were consistent with his or her expectations of human partners. This issue was not directly addressed with the participants; rather, the author drew the conclusion, based on the interviews, that the participants' expectations of desirable computerized partners (i.e., PALs) seemed to be consistent with those of human partners noted in a previous study (Beishuizen, Hof, Van Putten, Bouwmeester, & Asscher, 2001). In the current study, the participants yielded three major features to be addressed in designing a desirable PAL: PAL competency, PAL personality (or persona), and interaction control. Beishuizen and colleagues found that in classroom settings, students and teachers evaluated the characteristics of good human teachers (teachers they would wish to work with) in terms of expertise (knowledge and experience in a domain) and personality (e.g., friendliness, kindness, and enthusiasm). Although their study did not address the issue of interaction control, the author observed that the college students' expectations of a computerized PAL in the current study were not much different from their expectations of a good human partner, both emphasizing domain knowledge and personality. This may also support the contention that "media equals real life" (Reeves & Nass, 1996).

The uniqueness of the current study can be highlighted, however. This study identified the participants' *conscious* assumption that a PAL has a personality, in contrast to previous studies indicating users' "thoughtless" expectations and applications of social rules to computers. This difference may come from the assumed social presence of the anthropomorphized PAL in the current study, compared to studies that examined the users' reactions to computers more generally. In other words, given the human-like image on the screen, learners might consciously assume the image as sociable and expect to build a social relationship with the image. Furthermore, findings in the current study confirmed the gender difference in learner expectations that was indicated in an earlier study, where female students reported their liking of friends, interactions, and relationships more than did males (Lightbody & Siann, 1996). Also, regarding the gender difference in educational computing, Littleton and colleagues (1998) reasoned that one of the difficulties girls had with learning from many instructional programs was that the characters in those programs (warrior-like in general) were not appealing to them. The current study consistently revealed that the female participants favor a PAL with a friendly personality.

PHASE TWO: CONTROLLED EXPERIMENT

Given the emergent themes on desirable PAL characteristics, the next question was *How does learner competency interact with PAL competency and with interaction control?* Building social relations is a mutual (if asymmetric) process. According to social modeling research (Bandura, 1997; Schunk & Hanson, 1985), in conventional classrooms the characteristics of role models, such as competency and age, significantly interact with learner characteristics to influence a learner's self-efficacy and achievements. Likewise PAL/learner characteristics would interact to influence affective and cognitive attainments of learners. This expectation also seems supported by related studies (Bickmore, 2002; Gulz, 2004) indicating significant individual differences in a user's liking or disliking an animated character. The factors that determine those differences, of course, still invite exploration.

In Phase Two, therefore, the impact of PAL competency and interaction control was examined along with learner competency. Regarding PAL competency, Hietala and Niemirepo (1998) examined how EduAgents, strong or weak in domain knowledge, facilitated or frustrated young school children learning math. They found an interaction effect of learner and PAL competencies on collaboration, in which when the task was demanding, strong students (high IQ) more frequently asked for the strong agents' suggestions, whereas weak students (low IQ) more often asked for weak agents' suggestions. Although their study had only a limited number of participants, its findings are suggestive for the inquiry of the desirable levels of PAL competency for college students. Also, the issue of interaction control (e.g., program vs. learner control) has been actively investigated in conventional computer-based learning (Large, 1996; Ross, Morrison, & O'dell, 1989; Shin, Schallert, & Savenye, 1994; Steinberg, 1989). Those studies suggested that the investigation of interaction control should be pursued along with learner characteristics such as prior knowledge, cognitive style, and maturity. In particular, the importance of learner experience (novice versus experienced) has been emphasized in determining the efficacy of differing permutations of interaction control. Given a PAL's unique social presence, the initiation of the interactions between a learner and a PAL can be a variable affecting their social dynamic. It was expected that a learner's academic competency would interact with PAL competency and with interaction control in altering the learner's affect and cognition. Two specific questions guided the Phase Two: *1) Will the learner's academic competency interact with PAL competency to affect the learner's perceptions of a PAL, self-efficacy in the task, and learning? 2) Will the learner's academic competency interact with interaction control to affect the learner's perceptions of a PAL, self-efficacy in the task, and learning?*

Participants

Participants comprised 46 undergraduates (13 male and 33 female) in a computer-literacy course in a large public university located in the southeastern United States. The majority of the participants were freshmen and sophomores, 29% male and 71% female. Sixty-nine percent of the participants identified themselves as Caucasian, 14% as Hispanic, 7% as African-American, and 7% as other. The average age was 20.48 (*SD* = 1.64). Purposive sampling was used to include participants who did not have prior experiences in the domain of instructional planning, allowing for control over learner variations in domain experience. Self-report in the pretest indicated the homogeneity of their domain experience across the experimental conditions. The study was offered as an optional class activity, one for which the majority of the students volunteered to participate. No extra credit or incentives were provided for participation. The students were randomly assigned to experimental conditions by system programming.

Materials

Instructional Module

A computer-based instructional module introduced the students to the basic concepts of instructional planning in two phases: Blueprints and Plan (Kim, Baylor, & PALSGroup, 2006). The module started with an introduction telling the students that they were invited as instructional consultants to help improve a lesson on "supply and demand." Then the students were led to a case scenario of a 13-year-old girl, Anna, who was struggling to learn the economic concepts. Their task was to design a lesson for Anna. In the Blueprints phase, they wrote instructional goals and objectives to develop a lesson for Anna. In the Plan phase, they wrote instructional sequences, including strategies and activities. The participants were able to navigate the phases by clicking buttons at any time. As the module started, a PAL named Mike was introduced as a peer who would work with the learner. Mike stayed on the screen while the learner worked through the Blueprints and Plan phases. Referring to the information provided by Mike, students wrote their ideas in a given text-field (Workspace). Included in the module were two links to the Texas Benchmarks and Standards regarding appropriate instructional goals/objectives. With the exception of the links, the PAL was the only information source for students to learn instructional planning. The module was designed to take approximately 40 minutes for novices in instructional design. Figure 1 shows an example screen with Mike.

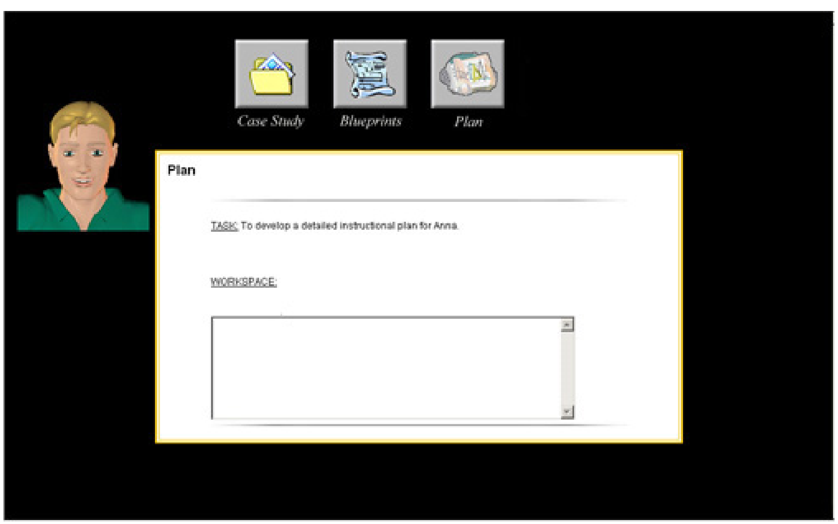

Fig. 1. Mike the PAL in the module

PAL Design

Based upon information derived from the interviews, the author (using Poser 4 implemented via Microsoft Agent) designed Mike to appear peer-like and friendly. Mike had the image of a peer in his early twenties, the target population for the study. He wore a casual shirt and spoke in an informal manner, sometimes using slang (e.g., "What's your gut feeling about it?"). The male gender was adopted based on the findings of previous studies indicating that both male and female college students prefer to interact with male partners in online discussions (Jeong & Davidson-Shivers, 2003) and that they perceive male pedagogical agents as more extroverted, agreeable, and satisfying than female agents (Baylor & Kim, 2004). Mike had a computer-generated voice, controlled for voice effects. Prior to the study, Mike's appearance was empirically validated with another sample of the target population. On the average, the participants in the validation study estimated his age to be 21.78 (*SD* = 2.34) and perceived Mike as peer-like.

Mike was not implemented with a dynamic AI module; his comments were all pre-scripted. Research indicates that even when agents were not equipped with intelligence, a learner tends to mistakenly assume the agents' intelligence, as if they provide dynamically-generated and adaptive responses (Xiao, Stasko, & Catrambone, 2004). It was considered prudent to examine the limited PAL/learner interaction as a preliminary step before examining more complex, generated agent/learner dialogues.

Independent Variables

PAL Competency

PAL competency, the PAL's domain knowledge of instructional planning, included two levels--low vs. high--and was operationalized by the PAL's scripts: i.e., the comments provided by the PAL to the students. The low-competency PAL was designed to simulate a novice peer lacking knowledge or experience in the task domain. To develop the scripts for the low-competency PAL, the researcher asked a group of novice undergraduates to create instructional plans and observed them as they worked in pairs. Conversations the pairs generated were scripted for the comments of the low-competency PAL. The low-competency PAL made his suggestions in the Blueprints and Plan phases, but his suggestions were not always accurate. At the beginning, the low-competency PAL stated his lack of experience but expressed a willingness to work with the learner (e.g., "I'm new in this area like you, but we can try to think of solutions together."). The suggestions included 8 idea units (Mayer & Gallini, 1990).

The high-competency PAL was designed to simulate an advanced peer. The comments of the high-competency PAL were based upon instructional design principles (e.g., writing goals and objectives and sequencing instructional activities) and translated into the conversational style of undergraduate peers. Thus, the high-competency PAL presented accurate information regarding how to perform the tasks. At the beginning, the high-competency PAL expressed his experience in the domain: e.g., "I'm quite confident in the area because of my earlier reading." The information provided by the high-competency PAL included 12 idea units. Table 1 presents the example scripts from the planning stage of the instructional module. In this particular example, the high-competency PAL offered four units of ideas; the low-competency PAL offered two. The styles of the high- and low-competency PALs differed slightly because the low-competency PAL scripts were based on classroom observation to increase naturalness. As a result, the low-competency PAL seemed to sound relation-oriented, whereas the high-competency PAL was purely task-focused (Gulz, 2005).

Interaction Control

Interaction control--PAL-control vs. learner-control--was determined by who initiated the learner/PAL interaction. In the PAL-control condition, the PAL initiated the interaction by proactively providing information or ideas, whether or not requested by the learner. That is, when a learner entered into a new phase, the PAL started to provide information that the learner needed to know in the phase. So the learner was forced to listen to Mike's comments before performing the task and was able to review the comments at any time. In the learner-control condition, the PAL provided information or ideas only at the learner's request, signaled by the learner's clicking the mouse on the PAL. When a learner entered into a new phase, Mike reminded them to "Click on me when you need my ideas." If a learner clicked on him, a list of his comments appeared, so that the learner could choose a relevant topic. In the Blueprints phase, for example, Mike's comments had two sub-listings: "How to get started" and "What it looks like." Otherwise Mike remained silent.

Learner Competency

Learners' academic competency, determined by their grade point averages (GPA), was one of two levels: strong or weak. Students having a GPA of 3.5 or above were categorized as strong; those having a GPA of 3.0 or below were categorized as weak.

Table 1
Example scripts in the Planning stage

Low-competency PAL	**High-competency PAL**
Hmmm… Hey, I can remember a really great class I took, and how well the instructor organized the class activities. Maybe we could refer to our personal experiences of good organization. This may be a good start to create a good plan.	Aha! I've learned before that we should have a good lesson sequence of four key steps. One, get the attention of learners. Two, review what they already know. Three, present the new information on 'Supply and Demand'. Four, give practice on what was taught.

* Underlined are idea units

Dependent Variables

Dependent variables were learners' perceptions of PAL functionality, self-efficacy beliefs in the task, and learning, as summarized in Table 2. Learners' perceptions of the PAL were measured by sub-measures of agent value, facilitation, and reflection. Learners' self-efficacy beliefs in the task were measured by self-report. Learning was measured by the two sub-measures of recall and application. In general, the researcher was motivated to examine the learners' engagement in the interaction with the PAL, speculating that if learners were more engaged, they would recall more of the ideas presented by the PAL. Recall of information and application of the information were regarded as distinct cognitive behaviors.

Agent Value

Agent value referred to learners' ratings on how helpful the PAL was. It was measured by a questionnaire with five items, scaled from 1 (*Strongly disagree*) to 5 (*Strongly agree*): 1) Mike was informative, 2) Mike was helpful, 3) Mike was credible, 4) Mike was motivating, and 5) Mike was supportive. Item reliability was evaluated as α = .90 (α *is an coefficient estimating correlations of the individual items).*

Facilitation

Facilitation referred to the learners' ratings of how much the PAL facilitated their learning. It was measured by a questionnaire with five items, scaled from 1 (*Strongly disagree*) to 5 (*Strongly agree*): 1) Mike kept my attention, 2) Mike made the instruction interesting, 3) Mike helped me concentrate on the information, 4) Mike focused me on the relevant information, and 5) Mike presented the ideas effectively. Item reliability was evaluated as α = .87.

Reflection

Reflection referred to learners' ratings of how much the PAL encouraged their reflective thinking. It was measured by a questionnaire with two items, scaled from 1 (*Strongly disagree*) to 5 (*Strongly agree*): 1) Mike led me to think more deeply about the information and 2) Mike encouraged me to reflect upon what I was learning. Item reliability was evaluated as α = .84.

Self-Efficacy

Learners' self-efficacy in the learning tasks was measured with a one-item question developed according to the guidelines by Bandura and Schunk (1981). The guidelines define self-efficacy as the degree to which one feels capable of performing a particular task at certain designated levels (Bandura, 1986). The participants answered the direct question "How sure are you that you can write a lesson plan?" on a scale ranging from 1 (*Not at all sure*) to 5 (*Extremely sure*) before and after the intervention.

Table 2
Dependent Measures

Variables	Measures	Items
Perceptions	Agent value	1) Mike was informative, 2) Mike was helpful, 3) Mike was credible, 4) Mike was motivating, and 5) Mike was supportive.
	Facilitation	1) Mike kept my attention, 2) Mike made the instruction interesting, 3) Mike helped me concentrate on the information, 4) Mike focused me on the relevant information, and 5) Mike presented the ideas effectively.
	Reflection	1) Mike led me to think more deeply about the information and 2) Mike encouraged me to reflect upon what I was learning
Self-Efficacy	-	How sure are you that you can write a lesson plan?
Learning	Recall	Open-ended
	Application	Open-ended

Recall

To assess learners' recall of information, the students were asked to write all the ideas about instructional planning conveyed by the PAL. According to a process implemented by Mayer and Gallini (1990), the idea units in the students' answers were counted and coded by two instructional designers with Masters' degrees in instructional design. Inter-rater reliability, evaluated as Cohen's *Kappa,* was .98. The numbers of ideas provided by the high-competency PAL and the low-competency PAL were not equivalent (see the section *PAL Competency*). Hence, students' recall scores were converted to *z*-scores for statistical analysis.

Application

To measure the participants' ability to apply what they had learned from the PAL to a new problem, the participants were asked to write a brief instructional plan according to a given scenario. The overall quality of a student's instructional plan was evaluated from an instructional-designer's perspective. Using a scoring rubric, the two instructional designers focused on the specificity of the students' plans in terms of the instructional topic and strategies. They scored students' answers on a scale ranging from 1 (*very poor*) to 5 (*excellent*). Inter-rater reliability, evaluated according to Cohen's *Kappa,* was .95.

Procedures

At the beginning, the participants were given a brief written introduction to the experiment. They were told that participation would not affect their course grades. They were asked to put on headsets to avoid distractions. The module was self-inclusive: the participants entered demographic information, took pre- and post-tests, and performed the learning task within the module. The participants logged on to the instruction web site and entered demographic information. Then they were asked to rate their experience in the task domain (instructional design) on a scale of 1 (*not familiar at all*) through 5 (*very familiar*); they rated their prior self-efficacy beliefs in the domain with the self-efficacy measure. After that, they performed the task with the PAL. The participants were given as much time as they needed to finish each phase of the task. The learning task of instructional planning took approximately 40 minutes, with individual variations. Lastly, they answered post-test questions, which consisted of two sections: Section 1 measured learning by open-ended recall and application questions; Section 2 measured learners' self-efficacy beliefs in the task and their perceptions of Mike, as assessed by agent value, facilitation, and reflection.

Design and Analysis

The study employed a $2 \times 2 \times 2$ factorial design, in which the variables included learner competency, PAL competency, and interaction control. To analyze the data, multivariate analysis of covariance (MANCOVA), with the pretest self-efficacy as a covariate, was first conducted. In statistical procedures, the inclusion of multiple dependent measures, as in the current study, can cause the inflation of family-wise error rates, resulting in falsely increased statistical significance. Generally, to strengthen the validity of statistical results, multivariate analysis techniques are recommended. Given the statistical significance from the MANCOVA testing, univariate analyses of variance (ANOVA) were conducted for each dependent measure, to identify the dependent variables that contributed to the rejection of the multivariate null. The significance level was set at $\alpha < .05$.

Results

A review of the data revealed no serious violation of the assumptions for multivariate procedures. The overall MANCOVA for protected testing revealed a significant interaction effect of learner competency and PAL competency, Wilks' Lambda = .41, F (6, 21) = 4.96, p < .01, partial η^2 = .59. The MANCOVA also revealed a significant interaction effect of learner competency and interaction control, Wilks' Lambda = .52, F (6, 22) = 3.29, p < .05, partial η^2 = .48. Given the results from the overall testing conducted to prevent the inflation of family-wise error rates, it was considered legitimate to further examine the interaction effects on each dependent measure. Thus univariate analyses (ANOVAs) were conducted to identify the contribution of each dependent variable to the overall effect. The results are summarized in Table 3.

Table 3
Summary of Findings by Dependent Variable

Measures	**Interaction Pattern**	
	Learner competency × PAL competency	Learner competency × Interaction control
Perceptions		
Agent value	The efficacy of high-competent PAL for strong students	▪ The efficacy of PAL-control for strong students ▪ The efficacy of learner-control for weak students
Reflection	The efficacy of high-competent PAL for strong students	--
Facilitation	The efficacy of high-competent PAL for strong students	--
Self-Efficacy	▪ The efficacy of high-competent PAL for strong students ▪ The efficacy of low-competent PAL for weak students	The efficacy of PAL-control for strong students
Learning		
Recall	▪ The efficacy of high-competent PAL for strong students ▪ The efficacy of low-competent PAL for weak students	--
Application	--	--

First, regarding the interaction between learner competency and PAL competency, the univariate results revealed significant interaction effects on learners' perceptions, self-efficacy, and learning (recall only).

For learners' perceptions, academically strong students perceived the high-competent PAL as significantly more valuable (F [1, 34] = 10.49, p < .01, partial η^2 = .29), more encouraging to reflective thinking (F [1, 34] = 4.16, p < .05, partial η^2 = .14), and more facilitative of learning (F [1, 34] = 6.48, p < .05, partial η^2 = .20) than the low-competent PAL. This trend was not shown among academically weak students. That is, the weak students' perceptions of high- and low-competent PAL were not differentiated.

For self-efficacy, F (1, 34) = 9.53, p < .01, partial η^2 = .27, academically strong students who had worked with the high-competent PAL showed higher self-efficacy beliefs in the task (M = 3.13, SD = 0.83) than did strong students with the low-competent PAL (M = 2.91, SD = 1.38), whereas academically weak students who had worked with the low-competent PAL showed higher self-efficacy beliefs (M = 3.57, SD = 0.53) than did weak students with the high-competent PAL (M = 2.221, SD = 0.67).

For recall, F (1, 34) = 5.54, $p < .05$, partial $\eta^2 = .18$, academically strong students who had worked with the high-competent PAL remembered more ideas than did strong students with the low-competent PAL, whereas academically weak students who had worked with the low-competent PAL recalled more ideas than did weak students with the high-competent PAL. For application, there was no significant difference across the conditions.

Second, regarding the interaction of learner competency and interaction control, the univariate results revealed significant interaction effects on agent value and self-efficacy. For agent value F (1, 34) = 7.11, $p < .01$, partial $\eta^2 = .21$, academically strong students rated the PAL as being more helpful in the PAL-control condition (M = 3.48, SD = 0.64) than in the learner-control condition (M = 2.58, SD = 1.08), whereas academically weak students rated the PAL as more helpful in the learner-control condition (M = 3.34, SD = 0.65) than in the PAL-control condition (M = 3.18, SD = 0.76).

For self-efficacy F (1, 34) = 7.51, $p < .01$, partial $\eta^2 = .22$, strong students (M = 3.60, SD = 0.70) showed higher self-efficacy than weak students (M = 3.11, SD = 0.78) in the PAL-control condition, whereas strong students showed lower self-efficacy (M = 2.33, SD = 1.22) than weak students (M = 2.43, SD = 0.98) in the learner-control condition.

To summarize, for the interaction of learner competency and PAL competency, academically strong students perceived the PAL more positively, showed higher self-efficacy, and recalled more after working with the high-competent PAL. This was not the case for academically weak students; rather, the weak learners showed significantly higher self-efficacy and recalled more after working with the low-competent PAL. For the interaction of learner competency and interaction control, the efficacy of PAL-control for academically strong students and the efficacy of learner-control for weak students on agent value and self-efficacy were indicated.

Discussion

The experiment was designed to investigate whether learners' academic competency interplayed with PAL competency and with interaction control to influence learners' perceptions of PAL instructional functionality, their self-efficacy in the task, and their learning. In general, the results revealed significant interaction effects.

First, academically strong students perceived high-competency PAL positively and showed higher self-efficacy beliefs in the task after working with the PAL. By contrast, academically weak students showed higher self-efficacy after working with low-competency PAL. These results mirrored the findings from a previous study (Hietala & Niemirepo, 1998) indicating that the collaboration between a learner and a learning companion was patterned according to the similarities of their competencies when the task was demanding – strong students' frequent collaboration with a strong agent and weak students with a weak agent. Also, weak learners' high self-efficacy in the task after working with weak agents has been indicated repeatedly in research on pedagogical agents (Baylor & Kim, 2004, 2005). The current study not only confirms this tendency with statistical rigor, but also reveals that the interaction of PAL and learner competencies influences learning (recall). A possible explanation for this phenomenon can be found in the concept of "attribute similarity," which Bandura (1997) describes as being necessary for effective social modeling in traditional human-to-human instructional settings. According to attribute similarity, learners often show high self-efficacy and better learning when they observe or work with partners whose personal characteristics—age, competence, ethnicity, and so on–resemble their own (Schunk, 1987). Similarly, learners in computing environments might feel more affiliated with the PAL they resemble. This feeling of affiliation might engender more positive attitudes towards the PAL, higher engagement in the interaction with the PAL, and better recall of the learned material at a later time. However, this interaction of learner and PAL competencies influenced only students' recall, not their application of learning. As a possible explanation, the author considered the short duration of exposure. Given that the participants were novices in the domain, a longer exposure to the environment might be required for deeper learning to be transferred into a novel problem. Future research may resolve this issue.

Second, academically strong students highly valued the PAL-control environment, i.e., working with a PAL that proactively provided information, whereas academically weak students tended to value the learner-control environment, where the PAL was responsive only to their request for information. Also, the strong students' self-efficacy was clearly differentiated according to the levels of interaction control: they showed higher self-efficacy in PAL-control but lower self-efficacy in learner-control than did weak students. A possible explanation for this result is that strong students as high achievers might be motivated to get new information or ideas provided proactively by the PAL. As they acquired the new information, their self-efficacy beliefs in the domain might follow. On the other hand, weak students might feel overwhelmed by a surplus of information they were not ready for. However, it seems important to state here that learner control might not be the best solution even for weak learners, given the learners' latency of using advisory help messages built into the system (Aleven & Koedinger, 2000; Dempsey & van Eck, 2003; van Eck & Dempsey, 2002). This observation poses another question about the appropriate timing of instructional support for weak students, the answering of which might be the next step in investigating this issue.

Overall the results confirmed previous findings that in agent-based environments, students and users have demonstrated divergent reactions to the social presence of agents (Bickmore & Picard, 2003; Gulz, 2005). A next inquiry might ask what creates this divergence. The experiment revealed learner competency as an influencing factor. Other learner characteristics – interactive styles, learning styles, etc. – might be worth investigating. Lastly, some limitations are noted. First, the different styles of the high- and low-competency PAL scripts that possibly would be an intervening factor were not controlled for in the experiment. Next, the impact on learning is limited only to recall (shallow learning); students' recall scores were low overall across the conditions, although the statistical significance was indicated. A possible explanation might be that the task domain was completely new to the participants and the task was optional. Their motivation to master the task might be low in general. Thus, the impact on learning should be generalized cautiously. Also, as mentioned earlier, the functionality of Mike (the PAL) was limited, all pre-scripted. The current study may serve as a preliminary step to proceed to the inquiry of a PAL with enhanced AI functionality. Subsequent research is invited to address the limitations of the study and confirm the findings.

CONCLUSION

The study focused on identifying the desirable characteristics of a PAL for college students. In Phase One, the qualitative inquiry yielded PAL competency, PAL personality (or persona), and interaction control. From this result, the author concluded that undergraduate students' *conscious* expectations of the desirable characteristics of their PAL were similar to expectations of a desirable human partner identified in a previous study. In Phase Two, the experiment further identified that one learner characteristic--academic competency–was a critical indicator to identify the desirable levels of PAL competency and interaction control. The learners' perceptions of the PAL and their self-efficacy in the task were clearly differentiated by both the PAL's and their own competencies, resulting in different degrees of learning (recall). Most noteworthy, the findings indicate that weak students can benefit from a PAL similar to themselves: a weak PAL, serving as a *coping model*, can help a weak learner build confidence and encourage him/her to persist in the task. From the instructional design perspective, a PAL should be designed in accordance with the characteristics of a learner to best support his/her self-efficacy and learning. The one-fits-all approach may not work in this environment. It seems less effective to create one "optimal" PAL, designed according to instructional designers' intuition or judgments. Rather, it is more likely that learners can benefit from multiple-PAL environments that provide a better opportunity to match with a learner's characteristics. This speculation may lend itself to inquiring in future research about the appropriate number of PALs to optimize instructional impacts.

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