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# Pedagogical Agents as Learning Companions: The Role of Agent Competency and Type of Interaction

□ Yanghee Kim, Amy L. Baylor, and PALS Group

*This study was designed to examine the effects of the competency (low vs. high) and interaction type (proactive vs. responsive) of pedagogical agents as learning companions (PALs) on learning, self-efficacy, and attitudes. Participants were 72 undergraduates in an introductory computer-literacy course who were randomly assigned to one of four treatments: Low-Proactive, Low-Responsive, High-Proactive, and High-Responsive. Results indicated a main effect for PAL competency. Students who worked with the high-competency PAL in both proactive and responsive conditions achieved higher scores in applying what they had learned and showed more positive attitudes toward the PAL. However, students who worked with the low-competency PAL reported significantly enhanced self-efficacy beliefs in the learning tasks. Also, there was a main effect for PAL interaction type. A proactive PAL had a significantly positive impact on recall. These different results on learning and motivational outcomes suggest that the competency and interaction type of a PAL should be designed according to the desired learning and motivational goals.*

**Keywords:** pedagogical agents; learning companions; human-computer interaction

□ A pedagogical agent-based environment suggests a new opportunity for computer-mediated learning emphasizing virtual social relations between learners and computers. *Pedagogical agents* are animated life-like characters (Johnson, Rickel, & Lester, 2000) that are included in instructional applications to simulate human instructional roles. Providing social interactions with

learners may make pedagogical agents distinctive from conventional courseware. A learner can learn content through interacting with one or more pedagogical agents, who may provide information or encouragement, share menial tasks, or collaborate with the learner. It may be desirable for pedagogical agents to possess human-like personae in order to create a social context for learning more naturally (Baylor & Kim, 2005; Erickson, 1997; Mulken, Andre, & Muller, 1998).

Pedagogical agents may help overcome some constraints of conventional computer-based learning. Traditionally, computer-based learning environments (e.g., intelligent tutoring systems) were used to support individualized learning, were tailored to meet individual students' needs, and supported each learner in the achievement of mastery learning (Aimeur & Frasson, 1996; Anderson, Corbett, Koedinger, & Pelletier, 1995; Chou, Chan, & Lin, 2003; Gertner & VanLehn, 2000; Graesser, VanLehn, Rose, Jordan, & Harter, 2001; VanLehn et al., 2000; Woolf, 1990). For instance, Cognitive Tutors, developed by Carnegie Learning, enhanced ninth graders' math learning by as much as a full standard deviation over control conditions (Koedinger & Anderson, 1997). However, these learning environments failed to provide situated social interaction that significantly influenced both learning and motivation (Lave & Wenger, 2001; Palinscar & Brown, 1984; Powell, Aeby, & Carpenter-Aeby, 2003; Vygotsky, Cole, John-Steiner, Scribner, & Soubberman, 1978; Wertsch, Minick, & Arns, 1984). It is well-documented that the cognitive functioning of learners is framed by social contexts (Adolphs & Damasio, 2000; Bower & Forgas, 2001; McInerney & Van Etten, 2000, 2002). Social interaction with other participants in classrooms influences learners' cognitive and affective characteristics (Skinner & Belmont, 1993; Sutton & Wheatley, 2003; Wong & Dornbusch, 2000). By simulating human instructional roles, pedagogical agents may provide learners with similar social contexts. Given that human-computer interaction is consistent with human-to-human interaction (Reeves & Nass, 1996), learners might become more engaged in learning tasks through social interaction with pedagogical agents.

Given the potential of pedagogical agents for learning, several studies have examined the instructional impact of pedagogical agent-based learning environments. Learners exposed to an environment with a pedagogical agent demonstrated deeper learning and higher motivation than learners without an agent (Moreno, Mayer, Spires, & Lester, 2001). Students in a voice-plus-agent environment outperformed those in a text-only environment and those in a voice-only environment on both process and product measures of learning. Similarly, students in the voice-plus-agent environment perceived worked-out examples as being less difficult than did their counterparts (Atkinson, 2002).

In order to design effective pedagogical agents, various human metaphors have been adopted. For instance, the agent AutoTutor plays the role of tutor (Graesser, Person, Harter, & Group, 2001). The agents Steve and Adele developed by CARTE represent experts in naval training tasks (Johnson et al., 2000). Baylor and Kim (2005) effectively simulated pedagogical agents who served distinct instructional purposes as an expert, a motivator, and a mentor. The current study was designed to focus on the role of pedagogical agents as *learning companions* by adopting a peer metaphor, as suggested in previous tutoring systems (Chan & Baskin, 1990; Chou et al., 2003; Goodman, Soller, Linton, & Gaimari, 1998; Hietala & Niemirepo, 1998; Kapoor & Picard, 2005; Kim, 2003a; Ryokai et al., 2003).

### Pedagogical Agents as Learning Companions (PALS)

In this study, we define PALS as animated peer-like characters that simulate peer interaction in computer-based learning. Bandura's social cognitive theory (2001) supports the benefits of human peer partners in intellectual and social development. According to Bandura, a great deal of psychological modeling occurs when learners see their everyday associates as similar to themselves. Learners tend to enhance their self-efficacy beliefs based on perceptions of peer models. Peer interaction can provide a free and open forum to facilitate a more active, and thus a more productive, exchange of ideas (Driscoll, 2000). Peer partners were often more effective than adult partners for learning and motivation in various subject areas across ages (Griffin & Griffin, 1998; King, 1998; Rowell, 2002; Topping et al., 1997; Yarrow & Topping, 2001).

Recognizing the potential of simulating peer interaction in computer-based environments, some researchers in computer science and artificial intelligence have built computer-based tutoring systems called learning companions to exploit different technologies (Xiao, Stasko, & Catrambone, 2004). They instantiated their learning-companion systems with various instructional functions, such as a peer tutor (Chan & Chou, 1997; Uresti, 2000), a collaborator (Chan & Chou, 1997; Dillenbourg & Self, 1992; Goodman et al., 1998; Hietala & Niemirepo, 1998), a competitor (Chan & Baskin, 1990), or a troublemaker (Aimeur & Frasson, 1996). These systems are somewhat differentiated from PALS in that most of the systems did not include virtual characters.

The issues commonly investigated in those studies were the competency (or expertise) of the systems and the interaction between the learner and the system. As a rationale for examining agent competence, Xiao and colleagues (2004) pointed out that the current status of agent technology is far from competent, so it might be important to examine user reactions to less-than-competent agents. Further, regarding agent role, agents as instructors or experts are

typically equipped with advanced competency in a domain, possibly playing a proactive role in providing information and demonstrating skills. In designing a PAL, however, issues of competency of the PAL and of the type of interaction need to be resolved. This is because the PAL should be perceived as peer-like and believable (Bates, 1992; Nijholt, 2001). Equipping a PAL with instructor-like advanced competency in a domain might undermine peer-likeness. Yet the PAL should be helpful for learning, motivation, or both. A PAL equipped with the appropriate levels of competency might effectively simulate human peer interaction and facilitate learning and/or motivation. Furthermore, the earlier studies cited were more geared toward system architecture and had some methodological weaknesses, for example, the limited number of subjects and weak statistical rigor.

Given that the differing levels of the competency of human peer models served different instructional goals (Schunk, Hanson, & Cox, 1987), it is necessary to know whether the high or low competency of a PAL will yield different outcomes in computing environments. Another variable in designing PAL-learner interaction is interaction control. In human peer interaction, there might be a type of implicit coordination of interaction turn-taking among peers. For learner-PAL interactions, designers face the question of who (the PAL, the learner, or either one) initiates the interactions. Yet whether the learner should be more or less active than the PAL is also not known. Kim (2004) interviewed college students about their expectations of the desirable characteristics of virtual peers, in which the students suggested that competency, interaction control, and personality were important characteristics to be addressed. In an earlier study, Kim (2003b) derived the key design constituents of a PAL in a social cognitive framework, where the competency and interaction type of a PAL were suggested as crucial design variables. Thus, the purpose of this study was to investigate the desirable levels of PAL competency and interaction type for college students' learning, self-efficacy, and attitude toward a PAL.

#### Competency Level: High Versus Low

The desirability of high-competency PALs is supported by instructional design guidelines that state that instruction should provide clear information to foster cognitive learning (Dick, Carey, & Carey, 2001; Gagné, Briggs, & Wager, 1992; Perkins, 1992). In a social cognitive framework, the theoretical constructs of the zone of proximal development (Vygotsky et al., 1978) and proxy agency (Bandura, 2001) emphasize the value of an advanced peer for learning. The zone of proximal development (ZPD) refers to the distance between a learner's actual and potential development. It further defines such

developmental functions that have not yet matured but are in the process of maturation through the assistance of others. In collaboration with these more capable others, learners can grow intellectually beyond the limits of their present capabilities. Proxy agency enables learners to use resources or the expertise of others in order to accomplish what they desire. Learners could thus take advantage of the knowledge of a high-competency PAL. Although the current technology is unable to fully feature the theoretical concepts in a PAL-based environment, the emphasis on advanced peers suggests that a high-competency PAL would be effective for a student's learning.

On the other hand, the high competency of a PAL might decrease a learner's self-efficacy beliefs in the task. When learners worked with peers who were academically weaker than themselves, their affective characteristics, such as self-esteem, confidence, and sense of responsibility, were significantly enhanced in both classroom-based (Cohen, Kulik, & Kulik, 1982; Topping, 2001) and computer-based environments (Aimeur & Frasson, 1996; Uresti, 2000; Uresti & Boulay, 2004). Also, the competency of a social model was a factor examined frequently in human peer model research. In a review of literature on peer modeling, Schunk (1987) noted that similarity in competency between a learner and a model might serve as an important source of self-efficacy information, especially in unfamiliar tasks, where the learner had little information on which to base self-efficacy judgments. Similarly, Bandura (1997) argued that learners lacking direct knowledge of their own capabilities rely more heavily on modeled indicators. Thus, it is plausible that learners, especially novice learners, would increase their self-efficacy beliefs in the task more by working with a less competent PAL than with a highly competent PAL.

#### Interaction Type: Proactive Versus Responsive

Learners might not be capable of making correct (i.e., effective and efficient) decisions in the process of their learning (Clarebout, Elen, Johnson, & Shaw, 2002). In such cases, information or advice should be provided proactively to enhance learning. In traditional computer-based instruction, learners achieved more when the system provided information than when they requested information on their initiative (Large, 1996; Ross & Morrison, 1989). Dempsey and van Eck (2003) also reported that 60% of graduate participants did not use the built-in adviser in computer-based statistics instruction. Novice learners used it even less (Gay, 1986; Ross, Morrison, & O'Dell, 1989; Steinberg, 1989). Alevan and Koedinger (2000) questioned the merits of student control in intelligent tutoring systems after they found out that ninth graders had not made use of help messages built into the system. Also, learners exposed to an intel-

ligent tutoring system in which a virtual tutor played an active role achieved higher learning than learners exposed to a learning-by-tutoring environment in which the learners actively taught a virtual tutee (Chan & Chou, 1997). Thus it seems that learners, especially novice learners, may attain higher learning when they work with a PAL that provides ideas proactively than with a PAL that responds only to their requests.

In contrast, according to Bandura (2001), the essential capacity of humanness is to exercise control over the nature and quality of one's life. With their own intention, learners may want to plan, select, regulate, and evaluate their learning tasks. This personal control enables one to "shape events to one's liking" (Bandura, 1997, p. 16). A learner may choose to learn with less interference from a PAL. Consider Microsoft "Clippy," an unwelcome intrusion to many users in Microsoft Office (Microsoft, 2001). Also, in conventional courseware design, learner control over the process of learning was supported mainly in terms of learners' affective gains, that is, enhanced motivation (Large, 1996). Thus, it is reasonable to expect that learners would show positive attitudes toward a PAL when it responds to their requests but remains silent and unobtrusive otherwise.

The application of PALs is a growing area in both technology and research. Given their unique potential as simulated virtual peers, it is unknown whether their instructional impact will be consistent with the findings from the research on peer-mediated learning and conventional computer-based environments. Research on human-to-human interaction is frequently replicated in media-based environments (Reeves & Nass, 1996); the hypotheses of the current study follow accordingly. First, it was expected that a high-competency PAL would be more effective for learning, given that its expertise would serve to enhance information acquisition (Hypothesis 1). Second, it was expected that a low-competency PAL would be more effective for self-efficacy, given that the learner could better identify with it as a peer, that is, "if he or she can do it; I can do it" (Hypothesis 2). Third, it was expected that a proactive PAL would be more effective for learning, given its initiation of more learner-PAL interactions (Hypothesis 3). Fourth, it was expected that a responsive PAL would have a positive impact on attitudes, given that learners may appreciate that their intentions or questions are reciprocated (Hypothesis 4).

## METHOD

### Participants

Participants were 72 undergraduates in a computer-literacy course conducted in a large public university located in the southeast of the United States. The

majority of the participants were freshmen and sophomores, 29% male and 71% female. Ethnicity data revealed that 69% of the participants were Caucasian, 14% Hispanic, 7% African American, and 7% 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 the 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 in 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 the computer system.

## Materials

The instructional module was a short version of MIMIC (Multiple Intelligent Mentors Instructing Collaboratively), a Web-based research environment that focuses on instructional planning. The short version included two phases out of the original three: Blueprints and Plan. The module started with an introduction telling 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. In the Blueprints phase, the participants 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 MIMIC started, a PAL named Mike was introduced as a peer who would work together with the learner. Mike stayed on the screen while the learner worked through the Blueprints and Plan phases. Included in the module were two links to the Texas Benchmarks and Standards regarding appropriate instructional goals and 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 min for novices in instructional design.

Prior to the study, we empirically validated the appearance of Mike with another sample of the target population. Mike was designed to have the image of a peer in his early 20s, because the target population for the study was college students. 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 perceive male pedagogical agents as more extraverted, agreeable, and satisfying than female agents (Baylor & Kim, 2004). Mike wore a casual shirt and

spoke in an informal manner, sometimes using slang (e.g., “What’s your gut feeling about it?”). The researchers used a computer-generated voice, controlling for voice effects. 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.

### Independent Variables

There were two independent variables in the study: competency (Low vs. High) and type of interaction (Proactive vs. Responsive). Thus, the study had four treatment conditions: a low-competency and proactive-interaction PAL (Low-Proactive), a low-competency and responsive-interaction PAL (Low-Responsive), a high-competency and proactive-interaction PAL (High-Proactive), and a high-competency and responsive-interaction PAL (High-Responsive).

*Competency.* Competency refers to the PAL’s domain knowledge of instructional planning. Competency included two levels—low versus high—and was operationalized by the PAL’s scripts: that is, the comments provided by the PAL to the students. The low-competency PAL was designed to simulate a novice peer who did not have knowledge or experience in the task domain. To develop the scripts for the low-competency PAL, the researchers asked a group of novice undergraduates in the domain to develop instructional plans and observed them working in pairs. Suggestions made by the pairs 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 eight 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 on 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: “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



Table 1 □ Example scripts of PALS in the planning stage.

<i>High-competency PAL</i>	<i>Low-competency PAL</i>
<p>Aha! I've learned before that we should have a good lesson sequence of five key steps. <u>One, get the attention</u> (1) of learners. <u>Two, review what they already know</u> (2). <u>Three, present the new information</u> (3) on 'Supply and Demand'. <u>Four, give practice</u> (4) on what was taught.</p>	<p>Hmmm . . . Hey, I can remember a really great class I have taken, and how well <u>the instructor organized</u> (1) the class activities. Maybe we could refer to our <u>personal experiences</u> (2) of good organization. This may be a good start to create a good plan.</p>
<p><i>Note:</i> Underlined are idea units.</p>	

high-competency PAL mentioned four idea units, and the low-competency PAL mentioned two idea units.

*Interaction type.* Interaction type, proactive versus responsive, was determined by who initiated the learner-PAL interaction. In the proactive condition, the PAL initiated the interaction by proactively providing information or ideas whether or not they were desired by the learner. That is, when a learner entered into a new phase, the PAL started to provide information that the learner need to know in the phase. So the learner was somewhat forced to listen to Mike's comments prior to performing the task of the phase, and the learner could listen to the comments again at any time if he or she desired to.

In the responsive condition, the PAL provided information or ideas only at the learner's request, for example, by clicking the mouse on him. When learners 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 sublistings: (a) "How to get started" and (b) "What it looks like." Otherwise Mike remained silent.

Dependent Variables

Dependent variables included learning, learners' self-efficacy in the task, and attitudes toward the PAL. We wanted 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

functions. Thus, learning was measured by the two submeasures of recall and application.

*Recall.* To assess learner recall of information, the students were asked to write all the ideas conveyed by the PAL about instructional planning. According to a process implemented by Mayer and Gallini (1990), the number of idea units in the student answers was counted and coded by two instructional designers, each having a master's degree in instructional design. Interrater reliability evaluated as Cohen's Kappa was .98. The number of ideas provided by the high-competency PAL and the low-competency PAL was not equal. Hence, student recall scores were converted to z-scores for statistical analysis.

*Application.* To assess the learners' ability to apply what they learned, the participants were asked to write a brief instructional plan according the following prompt:

Applying what you've learned, develop an instructional plan for the following scenario: Imagine that you are a sixth-grade teacher of a mathematics class. Your principal informs you that a member of the President's advisory committee will be visiting next week and wants to see an example of your instructional plan about the multiplication of fractions.

The overall quality of student instructional plans was evaluated from an instructional- design perspective. The two instructional designers scored the students' answers holistically (i.e., in terms of the traditional instructional design procedures) on a scale ranging from 1 (*very poor*) to 5 (*excellent*). Interrater reliability evaluated as Cohen's Kappa was .95.

*Self-efficacy beliefs in the task.* The learners' self-efficacy beliefs in the learning tasks—the degree to which they felt capable of performing the task competently—were measured with a one-item question developed according to the guidelines of Bandura and Schunk (1981): "How sure are you that you can write a lesson plan?" Responses ranged from 1 (*not at all sure*) to 5 (*extremely sure*). Learners were tested both before and after the intervention. This simple and direct item has been effectively used in previous studies (Baylor, 2002).

*Attitudes toward the PAL.* Learner attitudes toward the PAL referred to their perceptions of how informative the PAL was and how much he facilitated their learning. A questionnaire with 10 items was developed:

1. Mike was informative.
2. Mike was helpful.

3. Mike was credible.
4. Mike was motivating.
5. Mike was supportive.
6. Mike kept my attention.
7. Mike made the instruction interesting.
8. Mike helped me to concentrate on the information.
9. Mike helped me to focus on the relevant information.
10. Mike presented information effectively.

The students rated the PAL on a 5-point Likert scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Inter-item reliability, evaluated as Coefficient  $\alpha$ , was .90. The mean score of the 10 items was calculated for statistical tests.

#### Procedure

The experiment was conducted in regular classes of a computer-literacy course as a class activity. The participants were randomly assigned by the computer system to one of the four conditions: Low-Proactive ( $n = 21$ ), Low-Responsive ( $n = 14$ ), High-Proactive ( $n = 16$ ), and High-Responsive ( $n = 16$ ). The researchers administered the experiment with the assistance of the instructors.

At the beginning, the participants were given a brief written introduction about the experiment. They were told that participation would not affect their course grades. They were asked to put on headsets to avoid distractions from one another. They logged on to the instruction Web site and entered demographic information online. Prior to performing the task, they were asked to rate their experience in the task domain, instructional planning, on a scale of 1 (*not familiar at all*) to 5 (*very familiar*); then, 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 min, with individual variations. Lastly, they answered posttest questions. The posttest questions consisted of Section 1 (self-efficacy, recall, and application) and Section 2 (attitudes), taking an average of 10 min to complete.

## Design and Analysis

The study employed a  $2 \times 2$  between-subjects factorial design, including the variables of competency (Low vs. High) and interaction type (Proactive vs. Responsive). A multivariate analysis of covariance (MANCOVA) with prior self-efficacy as a covariate was employed for three reasons: first, to understand the interrelationship between the independent variables (competency and interaction type) and multiple dependent variables (student attitude, self-efficacy, recall, and application); second, to control for the inflation of familywise error rates expected with multiple dependent measures; and, third, to control for individual differences that appeared in pretest self-efficacy—even after random assignment, the participants' prior self-efficacy in the task was dissimilar across the conditions,  $F(1, 68) = 7.68, p < .01$ . If statistical significance was obtained from the overall protected testing, univariate analyses were conducted for each dependent variable to identify the dependent variables that contributed to the rejection of the multivariate null. The univariate analyses included two-way analyses of variance (ANOVAs) for attitude, recall, and application and analysis of covariance (ANCOVA) for self-efficacy.

## RESULTS

A review of the data revealed no serious violation in the assumptions for statistical procedures. The overall MANCOVA yielded a significant main effect for competency, Wilks's Lambda = .72,  $F(4, 61) = 5.81, p < .001$ , Partial  $\eta^2 = .28$ , and a significant main effect for interaction type, Wilks's Lambda = .85,  $F(4, 61) = 2.61, p < .05$ , Partial  $\eta^2 = .15$ . There was no overall significant interaction effect between competency and interaction type. The univariate analyses indicated that PAL competency had significant main effects on the application of learning, self-efficacy, and attitudes, and that PAL interaction type had a significant main effect on the recall of learning. Next, the directions of these results will be described by dependent variable (summarized in Table 2).

### Recall

The results revealed a significant main effect for PAL interaction type on learner recall,  $F(1, 68) = 9.67, p < .01$ . Students in the proactive condition ( $M = 2.18, SD = 2.17$ ) scored significantly higher than students in the responsive condition ( $M = 1.61, SD = 2.3$ ). The standardized effect size for this difference was Cohen's  $d = 0.78$ , which indicates a large effect according to Cohen's guidelines (1988). These results supported Hypothesis 3, stating that the proactive PAL would increase learning more than the responsive PAL.

### Application

There was a significant main effect for competency on student application of learning,  $F(1, 68) = 4.14, p < .05$ . Students in the high-competency condition ( $M = 2.63, SD = 1.39$ ) scored significantly higher than students in the low-competency condition ( $M = 2.03, SD = 1.19$ ). The standardized effect size for this difference was Cohen's  $d = 0.46$ , which indicates a medium effect according to Cohen's guidelines. Hypothesis 1, stating the positive impact of the high-competency PAL on learning, was supported by the results.

### Self-Efficacy

There was a significant main effect for PAL competency on self-efficacy in the task,  $F(1, 68) = 4.08, p < .05$ . Students in the low-competency condition ( $M = 3.00, SD = 1.18$ ) showed significantly higher self-efficacy about the task than students in the high-competency condition ( $M = 2.47, SD = 0.98$ ). The standardized effect size for this difference was Cohen's  $d = 0.49$ , which indicates a medium effect according to Cohen's guidelines. Hypothesis 3, stating the positive impact of the low-competency PAL on learners' self-efficacy beliefs in the task, was supported by the results.

### Attitude

There was no main effect of PAL interaction type on attitudes. Hypothesis 4—that the responsive PAL would have a positive impact on student attitudes toward the PAL—was not supported by the results. However, the results revealed a significant main effect of PAL competency on student attitudes toward the PAL,  $F(1, 68) = 16.58, p < .001$ . Students in the high-competency condition ( $M = 3.31, SD = 0.56$ ) reported significantly more positive attitudes toward the PAL than students in the low-competency condition ( $M = 2.62, SD = 0.91$ ). The standardized effect size for this difference was Cohen's  $d = 0.91$ , which indicates a large effect according to Cohen's guidelines.

Table 2 □ Summary of results by dependent variable.

<i>Dependent Variables</i>	<i>Efficacy of the PAL</i>
Recall:	Proactive Interaction Style > Responsive Interaction Style
Application:	High Competency > Low Competency
Self-efficacy in the task:	Low Competency > High Competency
Attitude toward the PAL:	High competency > Low competency

## DISCUSSION

The study was aimed at investigating the appropriate level of PAL competency and interaction type for undergraduate learners' cognitive and affective outcomes. We tested four hypotheses, based on human peer modeling research and theories of social cognition. The first hypothesis, that a high-competency PAL would be effective for learning, was partially supported by the results—only for application. The second hypothesis, that a low-competency PAL would be effective for self-efficacy, was supported. The third hypothesis, that a proactive PAL would be effective for learning, was partially supported—only for recall. The fourth hypothesis, that a responsive PAL would be effective for attitudes, was not supported. By those results, the study identified that PAL-learner relations were consistent with human peer relations in general. The implications of those findings are discussed by independent variables below.

#### Efficacy of the Highly Competent PAL on Application of Learning and Learner Attitudes

The results indicated the efficacy of the high-competency PAL for positively influencing student application of learning and attitudes toward the PAL. This was predicted by instructional design guidelines and by the theoretical constructs of the zone of proximal development (Vygotsky et al., 1978) and proxy agency (Bandura, 2001). The students were novices in instructional planning. The information provided by the high-competency PAL seemed to support their learning, which consequently led the students to perceive the high-competency PAL as being more helpful and facilitating than the low-competency PAL. A similar result was found in related research, indicating how a highly competent pedagogical agent, serving as an expert, led to improved learning over a low-competency agent, a motivator (Baylor & Kim, 2005). Regarding student attitudes toward agents, however, another investigation examining the impact of agent competence indicated that students' subjective views of an agent were highly related, not to the agent's utility, but to the perceived quality of the face and voice (Xiao et al., 2004). In that study, the high-moderate competence of the agents did not influence student perceptions of the agents. Rather, the students tended to blame themselves for the agents' poor performance or mistakes, assuming that the agent was intelligent even when it was not. They viewed the agent as friendly or intelligent according to the quality of the agent's voice and face. Efforts leveraging those findings from the previous and the current studies should be made in future research.

### Efficacy of the Low-Competency PAL on Self-Efficacy in the Task

Students who worked with the low-competency PAL reported significantly greater self-efficacy beliefs in the task than students who worked with the high-competency PAL. According to Schunk (1987), learners tended to increase self-efficacy in the task after they observed human peer models with low competency, especially in situations where learners were less familiar with the task. Consistently, novice learners in the current study might evaluate their own abilities as relatively high and feel more confident in instructional planning after observing the low-competency PAL. This finding is supported by Bandura's (1997) concept of attribute similarity as applied to PAL-learner relations in a computer-based environment. Bandura argued that people compare themselves more often to those who are similar to themselves, such as classmates or work associates. Surpassing associates raises efficacy beliefs, whereas being outperformed lowers them. Essentially, the low-competency PAL could have served as a "coping model" (Schunk et al., 1987) throughout the program, modeling for the learners how to cope with the novel situation as a novice, which in turn might have provided them with new possible strategies to replicate or ignore. This finding, that perceiving a pedagogical agent as being academically weak leads to increased learner self-efficacy beliefs, has been replicated in a number of other related pedagogical agent studies (Baylor & Kim, 2004, 2005).

According to Bandura (1986), the most functional efficacy judgments tend slightly to exceed what one can actually accomplish, and this overestimation serves to increase effort and persistence. It is open to question, however, to what degree students benefit from high perceptions of academic capability in the face of low achievements. Efforts to decrease students' relatively high self-appraisals should be discouraged. When they accurately understand what they know and do not know, however, students may be able effectively to deploy appropriate cognitive strategies while engaging in an academic task (Britner & Pajares, 2001).

### Efficacy of the Proactive PAL on Recall of Learning

Students who worked with the proactive PAL had significantly higher recall scores than students with the responsive PAL. Given the results, we examined the data from student interaction logs that recorded the number of student requests for information in the responsive PAL condition. The data showed that the number of their requests was less than half the total number of ideas that the responsive PAL was designed to deliver. This indicated that the students did not make use of all the information provided by the PAL as they

were supposed to. This phenomenon mirrored the findings from the previous studies aforementioned. This positive impact of a proactive agent was also indicated by Xiao and colleagues (2004). In their study that examined the competence of an interface agent, college students were more forgiving with agent errors made in proactive suggestions than agent errors made in reactive answers to their requests.

### Instructional Design Issues

The study revealed that the efficacy of the competency and interaction types of PALs depended on the learning outcomes, as hypothesized. This suggests that the competency and interaction type of a PAL should be designed according to the desired learning and motivational goals. This flexibility to design PAL characteristics depending on the learning context and intended outcome is a strength of a PAL-based environment over traditional human-peer-mediated learning and traditional computer-based environments.

Regarding PAL competency, PALs should be designed as highly competent for learning contexts in which instructional goals focus on knowledge and skill acquisition. On the other hand, in contexts where learners' self-efficacy beliefs in the task are a major concern, less competent PALs could be more effective. PALs can be deliberately designed as possessing a low competency in order to enhance learner motivation or confidence toward unfamiliar but important domains. Low-competency PALs serving as coping models can help build the confidence of novice learners and encourage them to continue the task.

Regarding interaction control, we recommend on the basis of the findings the proactive role of a PAL to actively provide learners, especially novice learners, with necessary information; this was also suggested in previous studies indicating learners' *rare* use of built-in help messages (Aleven & Koedinger, 2000; Dempsey & van Eck, 2003; van Eck & Dempsey, 2002). A number of studies, however, have indicated that the desirable type of interaction may interact strongly with other learner characteristics, such as prior knowledge, personality, cognitive styles, and maturity (age) of learners (Ross et al., 1989; Shin, Schallert, & Savenye, 1994; Steinberg, 1989). Different permutations of PAL-learner interaction might be beneficial, but only when considering the learner and task at hand. Future research is thus needed to investigate the source of interaction as it relates to more microlevel learner characteristics.

There were several limitations in the study. First, given that this study focused on a particular skill (instructional planning) over a limited period of time, it is questionable to generalize the findings to a context for a longer duration of time. Second, learner self-efficacy was measured with only one item,



which may have decreased the reliability of the results. Third, it is important to note that because the study was conducted purely on a voluntary basis without incentives, the learners in this study may not have been particularly motivated to learn the material, which was indicated in overall low recall scores across the conditions. Future research should consider using more motivated learners for comparison. Last, it may seem to be a limitation that the PALS employed in the study were not particularly “intelligent” but rather were prescribed to ensure similar learner experiences. As Xiao and colleagues (2004) pointed out, learners tend to assume that prescribed agents are providing dynamically generated and adaptive responses. Thus, we found that the advantage of controlling the agent-learner dialogues outweighed the possible loss of ecological validity (e.g., by not using truly conversational agents). Further, it is necessary to better understand learner interactions with interface agents before examining more complex intelligent agents. As Norman (1997) suggested, learners interact with agents as represented through their interface (e.g., persona), not through their underlying algorithms. □

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Yanghee Kim [yanghee.kim@usu.edu] is Assistant Professor in the Department of Instructional Technology at Utah State University, Logan, and the Director of the Center for Research on Engaging Advanced Technology for Education (CREATE) [<http://www.create.usu.edu>].

Amy L. Baylor is Associate Professor in the Department of Educational Psychology and Learning Systems at Florida State University and Director of the Center for Research of Innovative Technologies for Learning (RITL) [<http://ritl.fsu.edu>].

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