Expanding Preservice Teachers' Metacognitive Awareness of Instructional Planning Through Pedagogical Agents

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In this experimental study, 135 preservice teachers developed an instructional plan for a case study within the Multiple Intelligent Mentors Instructing Collaboratively (MIMIC) computer-based environment. Three-dimensional, animated pedagogical agents, representing constructivist and instructivist approaches to instructional planning, served as instructional mentors within the environment and were available to provide advisements. The research design consisted of two factors, (a) instructivist agent (present, absent) and (b) constructivist agent (present, absent), with two primary groups of dependent measures, (a) metacognitive awareness, and (b) attitude. Regarding metacognitive awareness, when the constructivist agent was present, participants tended to report a change in their perspective of instructional planning, reflected less on their thinking, and developed instructional plans rated as more constructivist in underlying pedagogy. Regarding attitude, when the instructivist agent was present, participants reported a more negative disposition regarding instructional planning. Results are discussed in terms of the impact on teaching instructional planning to preservice teachers.

In the field of instructional design, there are diverse theories and approaches to instruction (e.g., Driscoll, 2000). For preservice teachers, the importance of seeing how these theories relate to real instructional problems is critical. Two prominent yet differing approaches to instructional planning are (a) systematic instructional planning (here referred to as an instructivist approach), based on an objectivist epistemology, and (b) constructivism, based on an interpretivist epistemology (Jonassen, 1991). These two philosophical approaches lead to different understandings of human cognition and affect both the instruction that is developed and what evaluations are feasible and appropriate (Roblyer, 1996; Yarusso, 1992).

With its objectivist epistemic roots regarding knowledge, the underlying assumption of the instructivist approach to instructional planning is that knowledge can and should be transmitted from teacher to student. An objectivist approach to instructional planning emphasizes knowledge transfer, generally from a teacher, and skills are taught sequentially, incorporating individualized work with traditional assessment methods (Roblyer, Edwards, & Havriluk, 1997). This type of systematic approach to instruction has been shown to be effective due to its focus on clearly identifying goals and systematically developing instructional activities and assessment that lead to the attainment of the goals (Reiser & Dick, 1996).

In contrast, the epistemic roots of constructivism are in interpretivism, which maintains that knowledge is personally constructed within individuals and does not exist external to the in-

dividual. The constructivist approach tends to focus on more student-centered environments, to provide activities that facilitate knowledge construction and generative learning (e.g., Wittrock, 1990). Driscoll (2000) described five attributes of constructivist instruction: (a) embedding learning in complex and realistic environments; (b) providing for social negotiation; (c) supporting multiple perspectives and use of multiple modes of representation; (d) encouraging ownership in learning; and, (e) nurturing self-awareness of the knowledge construction process (pp. 382–383). To implement these features as part of the constructivist planning process, preservice teachers must learn to emphasize the *process* of learning more than the end product. Constructivist approaches have been found to be particularly beneficial for developing meaningful learning activities and engaging students in higher-order thinking (Jonassen, Peck, & Wilson, 1999).

One way to demonstrate these two distinct approaches authentically to preservice teachers would be through seasoned professionals modeling the approaches in the context of a real instructional situation. Exposure and interaction with several experts describing instructional content matter from different points of view can be very rewarding for the learner (Laurel, Oren, & Don, 1990) and can help the learner to establish the best personalized approach to understanding the content. Further, such exposure to multiple pedagogical perspectives could enhance preservice teachers' cognitive flexibility by requiring them to consider independently alternative points of view, and their metacognitive awareness of the differences between, and possibilities of, the perspectives. Metacognitive awareness of instructional planning is particularly desirable for novice instructional planners as it facilitates their understanding of the complexity and comprehensiveness of the planning process (Baylor & Kitsantas, 2001a; Kitsantas & Baylor, 2001).

Viewing an instructional problem from multiple perspectives is also desirable for promoting reflective thinking and problem solving, qualities important for preservice teachers who are learning to be teaching professionals. Further, as Jonassen (1997) described, instructional planning is an archetypal ill-structured problem because "the designer is constrained by circumstances, though in most design problems, there are a variety of solutions, each one of which may work as well as any other" (p. 69). Given that more than one problem-solving path is possible to reach a solution, the ability for a preservice teacher to take multiple perspectives when planning is appropriate and necessary. Yet, while it may be beneficial for preservice teachers to see their role in the classroom from multiple pedagogical perspectives (Bennett & Spalding, 1992), devising this sort of experiential exposure is difficult to implement with human instructors.

A promising possibility for demonstrating and experiencing different instructional approaches is through computer-based agents serving as pedagogical mentors (Baylor, 2002). A software agent is an independent computer program operating within software environments such as operating systems, databases, or computer networks (Roesler, 1994). Agents appear to have the characteristics of an animate being, and simulate a human relationship by doing something that another person could otherwise do for you (Seiker, 1994). Animated pedagogical agents have lifelike qualities, and can employ verbal instructional explanations together with nonverbal forms of communication (e.g., gaze, gesture, conveying emotion) in interacting with the learner. Along this line, Lester and colleagues (Johnson, Rickel, & Lester, 2000; Lester, Stone, & Stelling, 1999) have suggested that life-like agent characters are ideal to serve as tutors, coaches, or guides in knowledge-based learning environments.

An early research project, the Guides project (Oren, Salomon, Kreitman, & Don, 1990; Salomon, Oren, & Kreitman, 1989) as discussed by Erickson (1997), is an anecdotal study that investigated the issue of believability for agent-like computer programs. The project involved the design of an interface to a CD-ROM encyclopedia (focusing on early American history) with a set of travel guides, each of which was biased toward a particular type of information (settler woman, Indian, inventor). It was found that students tended to assume that the guides, which were presented as stock characters, em-

bodied particular characters. For example, because many of the articles in the encyclopedia were biographies, learners would assume that the first biography suggested was the guide's own! Students also wondered if they were seeing the article from the guide's point of view (they were not). Some of the students became emotionally engaged with the guides, one student getting angry that the guide had betrayed her; in another case the guide inadvertently disappeared and the student interpreted this as ". . . the guide got mad, he disappeared." As Erickson (1997) explained, while no controlled experiment was involved in these findings, rather these findings are anecdotal, it is hard to believe that the learner would have made such an inference if the suggested articles had been presented in a floating window that had vanished.

Building upon researchers' suggestions for agents to represent different "roles," such as characters in a play (Laurel, 1990, 1997) or social roles (Prendinger & Ishizuka, 2001a, 2001b), the next question to consider is if agents could represent different *instructional* roles. Although the idea of representing multiple instructional roles through computer-based media has been implemented in other research, there have been limited controlled studies.

The Experimental Toolbox for Interactive Learning Environments (ETOILE) system for teaching educational psychology principles (Dillenbourg, Mendelsohn, & Schneider, 1994) incorporated five agents, labeled after the teaching styles they implement: Skinner, Bloom, Vygotsky, Piaget, and Papert. The five teaching agents implemented decreasing level of directiveness: (a) Skinner worked step by stop, (b) Bloom made larger steps but with close control of mastery, (c) Vygotsky was based on participation, (d) Piaget intervened only to point out problems, and (e) Papert did not interrupt the learner. The ETOILE system also included a "coach" agent that was in charge of which tutor was used, although the learner could also select or remove a tutor. The ETOILE system was not designed for the purpose of instructional research, but rather to conceptualize the underlying engineering principles for the multiple agents; consequently, there is no empirical evidence regarding its instructional impact.

The Thinker Tools SCI-WISE system (White, Shimoda, & Frederiksen, 1999, 2000) incorporated a whole community of agents that give strategic advice and guide middle school students in the process of scientific inquiry. The agents each have particular areas of expertise, with general-purpose agents such as Ingrid the Inventor, or task-specific agents such as Quincy the Questioner or Helena the Hypothesizer. The agents thus serve as an explicit representation of the metacognitive processes involved in inquiry. For example, Ingrid the Inventor suggests heuristics such as "Turn your mind loose" and "Think of ideas and explore them," while providing specific examples and encouraging learners to evaluate their inventiveness. White et al. (2000) argued that metacognitive processes are most easily understood and observed in a multiagent system such as SCI-WISE. However, no formal evaluation has been reported.

Multiple Intelligent Mentors Instructing Collaboratively (MIMIC) is an agent-based learning environment developed for the purpose of instructional research (Baylor, 1999, 2001a, 2002). MIMIC situates instructional planning within a specific context: a case study of a 13-year-old girl struggling with the economics concepts of supply and demand. In MIMIC, agents explicitly represent the instructivist and constructivist perspectives of instructional planning and facilitate preservice teachers' internalization of these approaches. The animated three-dimensional pedagogical agents serve as scaffolds, providing cognitive support to preservice teachers while they write an instructional plan. The learner has control over the amount of assistance and when the agents will provide it. Preliminary research with MIMIC investigated the agents' viability as pedagogical mentors (Baylor, 2001a, 2002). Results indicated that participants who worked with both the instructivist and constructivist pedagogical agents simultaneously could differentiate between them and could explicate the two theories that they represented (Baylor, 2002). Further, these participants found both agents to be believable, useful, and credible, with no significant differences between the agents (Baylor, 2001a, 2002).

Hietala and Niemirepo (1998) suggested that the same social factors that occur in learning

communities with human beings are also influential in a learning community consisting of multiple artificial teaching and learning agents. They referred to this effect as a need for pedagogical multiplicity of teachers, suggesting that the many levels and complexities of the learning process might be alleviated by providing alternatives to the learner via an "extended family of intelligent agents." Essentially, an agent-based learning environment such as MIMIC allows preservice teachers to figuratively "put on different hats" and facilitates them in switching roles when solving an instructional problem. Through experiential interaction with the agents, the preservice teacher is facilitated in a deep approach to the task that focuses on the meaning of the instructional planning process itself, rather than a surface approach that involves simply writing an instructional plan following a "recipe." In this way, the preservice teachers' experience of instructional planning and the specific meaning it has for them could be considered as the most fundamental aspects of learning (Duffy & Jonassen, 1992; Marton & Booth, 1997).

If preservice teachers could interact with one or more instructional theories via pedagogical agents, how would this affect their performance in applying instructional planning principles to an authentic problem, and their corresponding awareness of and attitudes about the planning process? In particular, what characteristics of such an environment (e.g., presence of a particular pedagogical approach or agent combination) best promote metacognitive awareness of instructional planning? In this experimental study, it was hypothesized that the presence of both the instructivist and constructivist agents simultaneously (through their multiple perspectives) would most positively impact learner metacognitive awareness of instructional planning by increasing their reflection during the instructional planning process and changing their perspectives regarding instructional planning. Further, it was predicted that preservice teachers' transformation of metacognitive awareness would be reflected by the underlying instructivist or constructivist pedagogy of their instructional plans, depending on which agents are present.

It was not hypothesized that the presence of agents would affect performance in instructional planning given that it is generally found that the presence of agents does not significantly improve performance (Dehn & van Mulken, 2000). More recent evidence to the contrary (Atkinson, in press; Moreno, Mayer, Spires, & Lester, 2001) was limited to the well-structured knowledge domains of math and science, which may not generalize to the ill-structured domain of instructional planning. Given that the agents in MIMIC served as scaffolds to support the instructional planning process, it was predicted that their presence would positively influence participants' dispositions, self-efficacy and perceived instrumentality regarding instructional planning, as has been found with other support tools for instructional planning (Baylor & Kitsantas, 2001a, 2001b; Baylor, Kitsantas, & Hu, 2001; Kitsantas & Baylor, 2001).

METHOD

Design of study

The design of the study is summarized in Table 1. It initially consisted of three independent variables: *instructivist agent* (present, absent), *constructivist agent* (present, absent), and *agent character* (Peedy the Parrot, Merlin the Wizard). The agent character variable was assigned as a within-subjects factor to test for possible differences in agent character. After it was determined that agent character did not play a factor, that factor was removed from further analysis leaving the remaining two factors. There were two primary groups of dependent measures: *metacognitive awareness* (composed of change in perspective, self-reported reflection, and underlying pedagogy of instructional plan), and *attitude* (composed of self-efficacy, disposition, and perceived instrumentality). The attitude measures were each assessed pre- and postintervention. Performance, based on instructional plan total score, was also included as a dependent measure. Additionally, those participants who received both agents were asked to select the agent to which they were the more epistemologically similar.

Table 1 ☐ Overview of study design

Independent variables, and matrix of conditions:

		Constructivist agent	
		absent	*present*
Instructivist agent	*absent*	No agents	Constructivist agent only
	present	Instructivist agent only	Both agents present

Dependent variables:

	Specific measures
Metacognitive Awareness	• Change in perspective • Self-reported reflection • Underlying pedagogy of instructional plan
Attitude	• Self-efficacy toward instructional planning • Disposition toward instructional planning • Perceived instrumentality toward instructional planning
Performance	• Instructional plan total score

Sample

The sample consisted of 135 preservice teachers enrolled in eight sections of an "Introduction to Educational Technology" course at a southeastern public university. As part of this required course, the participants had already been taught an instructivist approach (Reiser & Dick, 1996) and a constructivist approach (Grabe & Grabe, 2001) to instructional planning, with identical course material (e.g., lectures, PowerPoint™ slides, assignments, exams) across the eight sections. Participation in this study was a required activity for class participants, and they received course credit for participating. The mean age of the sample was 19.76 years (*SD* = 2.13). Of those reporting ethnicity, 84% were White, 4% were Hispanic, 10% were Black, and 2% were of other groups. Of those reporting gender, 21.5% of the sample were male and 78.5% were female. The majority (60%) of the participants were sophomores, 27% were juniors, 7% were freshman and 6% were seniors. In rating their prior experience with instructional planning, the participant mean score was 2.23 (*SD* = .97) on a 5-point scale, where 1 = *no experience* and 5 = *very much experience*. Thus, overall, they had little prior experience. It is important to note that while participants had been exposed to both the instructivist and constructivist approaches to instructional planning, they were novices in implementing either approach.

MIMIC Environment

From the learner's perspective, MIMIC consists of an introduction, a case study, a blueprints stage, a plan stage, and an assessment stage. The introduction begins with the statement: "We are pleased that you have decided to join our educational consulting firm, Instruction Inc. Given your new skills in instructional planning, we have a project for which we really need your help." It then briefly describes the case-study situation involving 13-year-old Anna and her teacher, Mr. Lange. Next, participants are told that their task is to design a plan for Anna and her peers to learn this material, and that they may use any method they would like to solve the problem. Following this, the participant is instructed how to move throughout the environment. Depending on agent condition (see Pedagogical Agents section), the personal Advisors introduce themselves and their role. It is suggested to participants that they request information when possible from the Advisors, who have good ideas and much experience in instructional planning.

The environment organizes participant in-

structional planning processes into four main stages, which are described below: (a) case study, (b) blueprints, (c) planning, and (d) assessment. Each is indicated through large icon-buttons. At any time it is possible for the participant to move from one stage to the other, although it is not possible for the participant to return to the introductory screens. Once the participant enters the assessment stage, an additional button, labeled FINISHED, is provided. After selecting FINISHED, the participant is asked "Are you ready to exit the application and go to the exit survey?" After selecting OK, the participant answers postquestions. MIMIC was found to be easy to navigate in other research (Baylor, 2001a, 2002).

Case study. The case study was developed specifically for MIMIC because it is difficult to find existing case studies that are appropriate (Ertmer & Russell, 1995). It consisted of a description of Anna and her problems in learning supply and demand, her teacher Mr. Lange, and her school in Texas. The concept of supply and demand was chosen because it is relatively domain independent of specialty areas for instruction, and requires little specific prior knowledge. Links were provided so that the participant could access Anna's homework containing comments from Mr. Lange, and his personal planning notes including text and graphics. In this way, participants could review the necessary content for themselves as well as evaluate Anna's situation.

Blueprints. The purpose of this stage was listed on-screen as follows:

> . . . to decide what you want Anna to learn. What have you determined to be the learning goals? List them clearly in the workspace below. For reference you may want to see the stated Texas standards and benchmarks regarding supply-demand for eighth graders, with links below.

A text-box field was provided within which the participant could list the instructional goals or objectives. Two links provided additional information regarding Texas standards and benchmarks for supply-demand.

Planning. The purpose of this stage was listed on-screen as follows:

> To develop a detailed instructional plan for Anna.

A text-box field was provided within which the participant could enter the instructional plan.

Assessment. The purpose of this stage was listed on-screen as follows:

> To develop ways to determine if Anna learned what you initially defined in the blueprints stage. Please describe this assessment in detail in the space below.

A text-box field was provided within which the participant could list the assessment.

The MIMIC Web application was developed in terms of functionality according to factors regarding learner and agent control (Baylor, 2001b). Technically, it comprises a series of HTML forms within which the user interacts with Microsoft Agent characters, programmed by Visual Basic Script. Microsoft Agent was chosen because the agents are three-dimensional and animated, with built-in functionality. The core of the application's processing is done with server-side scripting, implemented with Cold Fusion. Cold Fusion Markup Language (CFML) is used to process all submitted forms, provide database interactivity, and allow the MIMIC environment to be set to variable configurations. Data are recorded to a Microsoft Access™ database.

Pedagogical Agents

Depending on the experimental condition, zero, one, or two Microsoft Agent characters (Peedy the Parrot or Merlin the Wizard) were implemented as Advisors to the participants. Characters were randomly assigned to represent the instructivist and constructivist agents and to control for possible differences. The Advisors were referred to by the gender-neutral names of Jan and Chris. Jan was always the instructivist advisor, representing traditional systematic instructional planning, including the problem-solving aspects of instructional systems design

(ISD) as characterized by Dick and Carey (1996) and Reiser and Dick (1996). Chris was always the constructivist advisor, representing a learner-centered approach, focusing on the importance of the context of learning, stressing that learning involves active interaction, and emphasizing the process rather than the product of learning (Driscoll, 2000).

The purpose of the agents was to serve as mentors (Baylor, 2000) and to operationalize the instructivist and constructivist approaches to instructional planning. When one or two agents were present the following events resulted:

1. The agents provide an initial observation when entering each of the four MIMIC planning stages.
2. The agents provide reflection questions every five minutes upon entering a stage. These questions encourage self-evaluation, and consist of statements,
   (a) Make sure you are not just talking about *how* you would do it; actually create the instruction for Mr. Lange (Anna's teacher),
   (b) Actually develop the content-related activities, or
   (c) Apply the plan specifically to the topic of supply and demand.
3. The agents provide an example of their instructional plans following the participant's development of an instructional plan.
4. The agents provide additional advisements when selected by the participant.

Agent advisements were specific to the case study and were developed and validated by experts in instructional planning together in consultation with of an economics professor. The available advisements (specific to each planning stage) appeared in a pop-up box for the participant to select. Several excerpts of agent advisements that could be selected by participants are listed in Table 2. Within MIMIC, there are a total of 13 agent advisements, including the advisement presented automatically as the participant entered each stage. By stage, the number of agent advisements were: case study (2); blueprints stage (3); plan stage (6); and assessment stage (2). See a related study (Baylor, 2002) for a complete listing and description of all agent advisements.

Measures

A list of the main dependent variables and associated measures is included in Table 1. Each dependent measure is described in the following section.

Metacognitive awareness. Metacognitive awareness was assessed through three dependent measures: (a) change in perspective in instructional planning, (b) self-reported reflective thinking, and (c) the underlying pedagogy of the participant-designed instructional plan. To assess a change in perspective of instructional planning, participants were asked, "Did using this program change your perspective of instructional planning?" which was coded as 1 (*yes*) or 0 (*no*). Next, they were asked to describe "Why or why not?" Two researchers comprehensively reviewed these open-ended answers (limited to those participants who reported changing perspective). Several coding categories emerged. Changed perspectives included: (a) instructional planning is more difficult or requires more thought than expected; (b) the program provided different approach or provided new ideas or insight; (c) student-centered lesson plans and multiple perspectives are important; (d) program provided structure and organization, making the process more specific; (e) program enhanced understanding of instructional planning; and (f) program elicited comments explicitly related to the value of the agents. Each answer was coded according to these six categories by two researchers, with 92% overall agreement. Disagreements were resolved through discussion.

To assess participants' self-reported reflections, they were asked, "How often did you reflect on your thinking during the process?" A Likert scale of 1–3, with *not at all*, *several times*, and *frequently* as the three levels, was used for responding.

To assess the underlying pedagogy of the instructional plans, they were scored according to their underlying pedagogy, on a scale from 1 to 10. Given that certain instructional plan features are representative of both instructivist and constructivist pedagogies (e.g., the importance of considering prior knowledge), the purpose of this measure was to determine whether the

Table 2 ☐ Several examples of agent advisements, by agent and stage of planning within MIMIC

Stage	*Type of advisement*	*Constructivist agent*	*Instructivist agent*
Case study[a]	Initial observation	The concept of supply and demand is not being made real to the students. Perhaps it needs to be presented more realistically so that they can identify it in their own lives.	The instruction is not working because it is not systematically planned-out. There needs to be a better match between what the students need to learn about supply and demand and the actual activities that they do to learn it.
Blueprints	Initial observation	Consider what you want Anna to learn, but leave some room so that she can have some choice.	State your goal as clearly as possible- this is a key step.
Blueprints[b]	Additional advisement: *What is the purpose of the goals?*	. . . to set the context for learning so that the focus can be on the learning process itself. The instructor must provide constraints for the learner, to guide the process, so that she will not be frustrated.	The instructor (or designer) should create the goals as specifically and as clearly as possible. To define what the learner must learn so that appropriate learning activities can be designed.
Plan	Initial observation	I believe the goal is for Ann to create the information for herself.	I believe the goal is for Anna to obtain the information from the instructor.
Plan[c]	Additional advisement: *What is my role in the learning process for Anna?*	Anna should be at the center of the learning process. This will encourage Anna's initiative, get Anna to think and to reflect, and make the information real for Anna.	You need to be in charge of the learning process for Anna. You need to organize the materials for Anna, to create an optimal learning environment.
Assessment	Initial observation	Think of an authentic situation in which Anna and her classmates could demonstrate their skills.	Here you need to determine if the goals you set initially are met.
Assessment	Additional advisement: *What is the purpose of assessment?*	. . . for Anna and her classmates to perform a real-world task to model *their learning regard*ing the subject.	. . . for Anna and her classmates to demonstrate the knowledge that they learned.

Notes:
a The case study stage also had one additional advisement
b The blueprints stage had a total of two additional advisements
c The plan stage had a total of five additional advisements

plans represented features that were more representative of an instructivist or a constructivist approach. After careful analysis of the plans, it was determined that assessing the presence of constructivist characteristics was the most viable means of differentiating the plans by pedagogy because the constructivist features were the most salient to detect. Arbitrarily, it was determined that a high score would indicate the presence of more constructivist aspects to the plan, such as a student-centered approach, student involvement with constructing knowledge, a focus on student reasoning or critical thinking, and situated learning. A low score in this

measure indicated that there were fewer constructivist and more characteristically instructivist elements within the plan.

Two of the researchers met and together discussed what characterized a score of 1–10 for the presence of underlying pedagogy (where 1 = *not at all constructivist* and 10 = *highly constructivist*) for five sample instructional plans. For example, plans scored as highly constructivist included instructional activities such as economic simulations (e.g., designing and selling a new product to their classmates using play money) where students discovered the economic principles of supply and demand for themselves with the guidance of the teacher. Plans scored as low in constructivism (high in instructivism) were characterized as more teacher-directed in approach (e.g., lecture, worksheets, video), with more structured information presentation (e.g., presenting definitions and interrelationships of the key words: opportunity, cost, scarcity, surplus, buyer, seller, and supply and demand). Following agreement on scoring criteria, each researcher independently scored 15 instructional plans. Interrater reliability between the two researchers was determined to be greater than .9 for the 15 instructional plans. One of the researchers then scored the remainder of the instructional plans using the same rating scale. Both researchers were blind as to the conditions of the participants throughout the rating process.

Attitudes. Attitudes were assessed by three dependent measures: self-efficacy, disposition, and perceived instrumentality. One item to measure student self-efficacy beliefs about instructional planning was administered before entering and after exiting the MIMIC environment. It was developed based on Bandura and Schunk's (1981) guidelines for specificity, given that *self-efficacy* is the degree to which one feels capable of performing a particular task at certain designated levels (Bandura, 1986). All participants were asked, "How sure are you that you can write a lesson plan?" on a scale from 1, *not sure,* to 9, *very sure.* The correlation of pre- and postscores was $r = .62$, $p < .001$.

To assess participant disposition toward instructional planning, each participant was asked both before and after the intervention to write two adjectives to "Describe what you think about instructional planning." This method was employed to obtain the participants' personal affect regarding instructional planning as opposed to the response set that could bias them to choose more favorable adjectives if adjectives were presented in a list. The adjectives were coded according to three levels: –1 if both were negative, 0 if one was negative and the other positive, and +1 if both were positive. Two raters coded the items independently. Interrater reliability was established at $r = .95$ for the two raters, based on the scoring of 15 protocols. The only two disagreements about the scoring were resolved through discussion. Two adjective pairs were discarded because they could not be classified. The correlation of pre- and postscores in this study was $r = .55$, $p < .001$. The concurrent validity of this measure was supported in Kitsantas and Baylor (2001) by a significant positive correlation between initial disposition and initial self-efficacy scores. Prior research has shown that self-efficacious students generally have positive affect (Bandura, 1986).

To assess the participants' perceived instrumentality, or perceived importance of instructional planning, the participants were asked to rate "How important is writing a lesson plan to you as a future professional?" on a scale of 1 to 5, where 1 = *not important,* 2 = *fairly important,* 3 = *important,* 4 = *very important,* and 5 = *-extremely important.* This measure was implemented both before and after the intervention. The correlation of pre- and postscores was $r = .83$, $p < .001$.

Instructional planning performance. Within MIMIC, all participants developed an instructional plan to teach the concepts of supply and demand to Anna. Each instructional plan was scored according to a rubric that consisted of four sub-areas. The four subareas of the rubric were (a) goals and objectives, (b) procedure, (c) assessment, and (d) holistic, the first three being aligned with the corresponding major components of instructional planning.

For the goals and objectives subscore, the plans were rated according to how clearly the goals and objectives were stated and how

specifically the purpose of instruction was described. For the procedure subscore, the plans were rated according to the meaningfulness and effectiveness of the instructional activities, if they were in a logical sequence, and if they addressed the goals stated in the blueprints stage. For the assessment subscore, the plans were rated according to if the assessment matched the goals and objectives, and if it was logical. For the holistic subscore, the plans were rated according to if the overall plan was reasonable and effective. The overall performance score was the compilation of these four subscores (each rated from 1 to 5), with a potential range of 4–20.

Two of the researchers met and together discussed what characterized a score of 1 through 5 (where 1 = *poor* and 5 = *excellent*) for each of the four subareas for five sample instructional plans. Following that activity, each researcher independently scored 15 instructional plans. Interrater reliability between the two researchers was determined to be greater than .9 for those plans. One researcher then scored the remainder of the instructional plans using the same rubric. Both researchers were blind as to the conditions of the participants throughout the rating process.

Agent more epistemologically similar. Participants receiving both agents were asked the following forced-choice question: "Who <instructivist or constructivist agent> thought more like you?" If participants selected the constructivist agent, they were assigned a *1,* and if they selected the instructivist agent they were assigned a *2.*

Procedure

There were no significant differences in age and grade point average among the participants in the four conditions. Chi-square analyses revealed no significant differences among the groups in ethnicity, gender, and year in school.

All participants logged into the MIMIC computer environment and answered computer-based questions regarding gender, age, and class section number. Next, the participants' perceived instrumentality, disposition regarding instructional planning, prior experience with instructional planning, and self-efficacy beliefs toward instructional planning were assessed. Following these initial measures, the participant entered the introduction to the MIMIC environment (see the MIMIC section) and was randomly assigned to one of the four conditions. Next, the participants worked through the case study, blueprints stage, planning stage, and assessment stage, to develop an instructional plan. Depending on the condition (see Pedagogical Agents section), 0–2 agents were present within the environment, serving to represent instructional planning approaches (instructivism, or constructivism, or both). All participants worked independently within the environment at their own pace.

Following completion of the instructional plan within the environment, all participants answered computer-based questions regarding amount of self-reflection, change in perspective of instructional planning, perceived instrumentality, disposition, and self-efficacy. Participants who received both agents were asked to select the agent that was more epistemologically similar to themselves. The entire procedure took approximately 90 min.

Data Analysis

The data were analyzed according to two groups of dependent measures: (a) metacognitive awareness (composed of change in perspective, reflection, and underlying pedagogy of instructional plan), and (b) attitude (composed of self-efficacy, disposition, and perceived instrumentality), as shown in Table 1. Metacognitive awareness was assessed via a two-factor multivariate analysis of variance (MANOVA) (Instructivist Agent: present, absent × Constructivist Agent: present, absent). Attitude was also assessed via a similar two-factor MANOVA using the postintervention scores. The preintervention scores were used to determine that there were no initial differences in attitude. Instructional planning performance was evaluated by a two-factor analysis of variance (ANOVA), with the total instructional planning performance score as the dependent measure. For participants receiving both agents, a one-sample *t* test was used to analyze which agent they reported as more epistemologically similar. In a

post hoc exploratory manner, independent *t* tests were conducted to compare high versus low performers in terms of metacognitive awareness and as to which agent they reported as more epistemologically similar.

RESULTS

The means and standard deviations for all dependent variables are presented in Table 3. This table is organized according to the presence and absence of the constructivist and instructivist agents (i.e., main effects), and also according to the four participant conditions (no agents, instructivist only, constructivist only, and both agents). In the following subsections, results are described for metacognitive awareness (quantitative and qualitative), attitude (quantitative), performance (quantitative), and agent more epistemologically similar (quantitative). A separate section describes the supplementary analyses for high and low performers.

Metacognitive Awareness

Metacognitive awareness was analyzed through a two-factor MANOVA, with change in perspective regarding instructional planning, amount of self-reflection, and underlying pedagogy of the instructional plan as the dependent measures, and with the instructivist agent (present, absent) and the constructivist agent (present, absent) as the two between-subject factors. The two-factor MANOVA indicated that there was an overall effect of the constructivist agent on metacognitive awareness, Wilks's Lambda = .806, $F(3,129) = 10.37$, $p < .001$. ANOVA indicated that significant differences occurred in all three dependent measures, as is described in the next subsections.

Perspective of instructional planning. Univariate results revealed a main effect for the constructivist agent on change in perspective in instructional planning, indicating that when the constructivist agent was present participants were more likely to report that MIMIC changed their perspective of instructional planning than when it was absent, $F(1, 131) = 9.82$, $MSE = 2.26$, $p = .002$. The effect size estimate was $d = .52$, indicating a medium effect (Cohen, 1988).

Of the 79 participants who reported changing perspective, 76 provided reasons. Given the main effect for the constructivist agent on change in perspective, the qualitative analysis (see Table 4) of their reasons was organized according to whether these participants had the constructivist agent present or absent. Many participants cited realizing the difficulty of instructional planning (e.g., "Well I think there are a lot more things to take into consideration that I would have thought") whether the constructivist agent was present or absent. Those participants who had the constructivist agent present were four times as likely as those who did not receive the constructivist agent to attribute their change in perspective to the focus on student-centered or multiple perspectives, twice as likely to attribute it to program-inspired new ideas (e.g., "It allowed me to process my thinking a lot better. . . . I felt as though I actually had ideas, when beginning the material I was clueless"), and explicitly to the presence of agents. Those participants who changed perspective but did not receive the constructivist agent tended to attribute it more to the structure of the program (e.g., "The program laid out the design plan for me. It made it easier to plan the design because I did not have to stop and remember what I have to do next ") and were twice as likely as those who received the constructivist agent to attribute it to the fact that they gained a better understanding of instructional planning. Despite these descriptive trends, chi-square analyses revealed no significant differences among the frequencies represented by these categories.

Self-reported reflection. Univariate results revealed a main effect for the constructivist agent, indicating that when the constructivist agent was present ($M = 2.25$, $SD = .49$), participants reported reflecting *less* than when it was absent ($M = 2.44$, $SD = .53$), $F(1, 131) = 4.73$, $MSE = 1.21$, $p < .05$. The effect size estimate was $d = .37$, indicating a medium effect.

Underlying pedagogy of instructional plan. Univariate results revealed a main effect for the constructivist agent, where the presence of the constructivist agent was related to participants developing more constructivist-oriented in-

Table 3 □ Means and standard deviations for the dependent variables.

			By Main Effects				By Condition			
			Instructivist Agent		Constructivist Agent					
Dependent Variable	*Measures*		*absent (n=62)*[h]	*present (n=73)*[i]	*absent (n=62)*[j]	*present (n=73)*[k]	*No Agents (n=32)*	*Instructivist only (n=30)*[l]	*Constructivist only (n=30)*[m]	*Both Agents (n=44)*
Metacognitive Awareness	Change in perspective[a]	*M*	.61	.56	.45	.70	.44	.47	.80	.63
		SD	.49	.50	.50	.46	.50	.51	.41	.49
	Self-reported reflection[b]	*M*	2.39	2.29	2.44	2.25	2.56	2.30	2.20	2.28
		SD	.52	.51	.53	.49	.56	.47	.41	.55
	Underlying pedagogy of instructional plan[c]	*M*	5.69	5.05	4.48	6.08	4.78	4.17	6.67	5.67
		SD	2.99	3.01	3.02	2.82	3.14	2.90	2.52	2.97
Attitude (Pre-treatment measure listed in parentheses)	Self-efficacy[d]	*M*	(5.32) 5.97	(5.67) 6.08	(5.39) 5.85	(5.61) 6.18	(5.34) 5.75	(5.45) 5.97	(5.29) 6.21	(5.81) 6.16
		SD	(2.36) 1.88	(2.06) 1.84	(2.20) 1.90	(2.21) 1.81	(2.31) 2.00	(2.11) 1.82	(2.46) 1.73	(2.03) 1.88
	Disposition[e]	*M*	(.72) .74	(.55) .49	(.69) .63	(.57) .58	(.75) .72	(.63) .53	(.69) .76	(.49) .47
		SD	(.58) .54	(.69) .63	(.62) .61	(.67) .60	(.57) .63	(.67) .57	(.60) .44	(.70) .67
	Perceived instrumentality[f]	*M*	(4.23) 4.30	(4.03) 4.08	(4.23) 4.26	(4.03) 4.11	(4.22) 4.31	(4.24) 4.21	(4.25) 4.29	(3.88) 4.00
		SD	(.87) .91	(.95) .98	(.88) .87	(.94) 1.01	(.91) .86	(.87) .90	(.84) .98	(.98) 1.02
Performance	Instructional plan score[g]	*M*	12.85	13.45	12.73	13.55	12.66	12.82	13.05	13.90
		SD	4.09	4.11	4.16	4.04	4.05	4.34	4.19	3.94

Notes:

a Possible range for change in perspective (0-1)
b Possible range for self-reported reflection (1-3)
c Possible range for underlying pedagogy of instructional plan (1-10)
d Possible range for self-efficacy (1-9)
e Possible range for disposition (-1 to 1)
f Possible range for perceived instrumentality (1-5)
g Possible range for instructional plan score (4-20)
h n = 60 for attitude measures only
i n = 72 for attitude measures only
j n = 61 for attitude measures only
k n = 71 for attitude measures only
l n = 29 for attitude measures only
m n = 28 for attitude measures only

structional plans than when it was absent, $F(1,131) = 11.28$, $MSE = 95.02$, $p = .001$, with an effect size estimate of $d = .55$, indicating a medium effect.

While there was not a statistically significant main effect for the instructivist agent, it approached significance ($p = .10$). Showing a similar trend, the presence of the instructivist agent was associated with lower scores on the measure, thus indicating its positive relation to underlying instructivist pedagogy. The effect size estimate was $d = .21$, indicating a small effect.

Attitude

Attitude was analyzed through the two-factor MANOVA design, with disposition, self-efficacy, and perceived instrumentality as the dependent measures. A preliminary two-factor

Table 4 ☐ Percentages of categorical responses for change in perspective by presence or absence of constructivist agent

Category of response	Constructivist agent % present (*n* = 49)	% absent (*n* = 27)
Difficulty of instructional planning	29	33
Generated new ideas	23	11
Program added structure and facilitated the process	20	33
Greater understanding of instructional planning	8	19
Focus on student-centered instruction & importance of multiple perspectives	12	3
Presence of agents (explicitly)	8	0

Table 5 ☐ Percentages of categorical responses for change in perspective by high and low performers

Category of response	% High Performers (*n* = 40)	% Low Performers (*n* = 35)
Difficulty of instructional planning	25	50
Generated new ideas	18	5
Program added structure and facilitated the process	31	20
Greater understanding of instructional planning	18	25
Focus on student-centered instruction & importance of multiple perspectives	0	5
Presence of agents (explicitly)	0	0
Other	6	0

MANOVA was conducted using the preintervention scores, which confirmed that there were no initial differences for attitude. The two-factor MANOVA on postintervention scores yielded an overall effect of the instructivist agent on attitude, Wilks's Lambda = .968, $F(3,129) = 2.865$, $p < .05$.

ANOVA indicated that significant differences occurred only in disposition. A main effect showed that when the instructivist agent was present ($M = .49$, $SD = .63$), participants had significantly more negative dispositions regarding instructional planning than when the instructivist agent was absent ($M = .74$, $SD = .54$), $F(1, 131) = 6.950$, $MSE = .383$, $p < .01$. The effect size estimate was $d = .43$, indicating a medium effect.

Instructional Planning Performance.

Instructional planning performance was analyzed through a two-factor ANOVA with the total instructional plan score as the dependent measure. Results revealed no main effects or significant interactions.

Agent More Epistemologically Similar

Participants who received both agents tended to report that they thought more like the constructivist agent ($M = 1.40$, $SD = .49$), where 1 = *constructivist agent* and 2 = *instructivist agent*. However, this difference was not statistically significant as assessed by a one-sample t test, $p = .17$.

Post Hoc Analyses of High and Low Performers

Post hoc supplementary analyses of high and low performers were conducted for metacognitive awareness and as to which agent was more epistemologically similar. High performers ($n = 40$) were defined as those in the highest quartile for instructional plan score ($M > 16$), and low performers ($n = 35$) included those with scores in the lowest quartile ($M < 10$).

Metacognitive awareness. In terms of perspective of instructional planning, a post hoc independent t test revealed that low performers tended to have a change in perspective more than the high performers, ($M = .69$ vs. $M = .45$), $t(73) = 2.08$, $p < .05$. Qualitative data analysis (see Table 5) showed that both high performers and low performers attributed change in perspective to the realization of the difficulty of instructional planning, but such attributions were twice as frequent for the low performers (e.g.,

"<MIMIC> made me think more, and how much work goes on in one lesson") than for the high performers. Both the high and low performers also attributed their change in perspective to a greater understanding of instructional planning (e.g., "I know a lot more about the process now, that it requires a lot of thought and creativity"). But the high performers who changed perspective were more likely to attribute it to the structure of the program (e.g., "<MIMIC> helped me organize my thoughts more than just using a piece of paper") and three times as likely to the ideas that they generated (e.g., "<the agents> helped guide me, and took some of the pressure off of <doing it> 'the right way' since you were given two different perspectives of suggestions") as compared to the low performers. Despite these trends, the differences among categories were not statistically significant as tested via chi-square analysis.

With regard to self-reported reflection, a post hoc independent *t* test showed no significant differences between high and low performers in terms of self-reported reflection, $p = .88$. On the measure of underlying pedagogy of instructional plan, a post hoc independent *t* test showed that high performers developed plans that were significantly more constructivist ($M = 6.08$, $SD = 3.05$) in approach than low achievers ($M = 4.29$, $SD = 3.00$), $t(73) = 2.56$, $p = 01$. The effect size estimate was $d = .59$, indicating a medium effect.

Agent more epistemologically similar. As assessed by a post hoc independent *t* test, low performers were significantly more likely to report thinking like the constructivist agent ($M = 1.13$, $SD = .35$) than high performers, who tended to think more like the instructivist agent ($M = 1.63$, $SD = .50$), $t(19.09) = 2.83$, $p = .01$. The effect size estimate was $d = 1.16$, corresponding to a large effect.

DISCUSSION

Overall, the results indicate that the presence of the constructivist pedagogical agent affected preservice teachers' metacognitive awareness of instructional planning in multiple ways: through a change in perspective, less reported reflection, and through the underlying pedagogy of their instructional plans.

Increased metacognitive awareness about instructional planning would probably lead preservice teachers to a richer and more comprehensive understanding and appreciation of the planning process. As stated by Marton and Booth (1997), "of prime interest is the variation in the ways in which people are capable of experiencing various situations or phenomena. If one becomes aware that something is in a certain way, they also become aware that it could be in some other way" (p.207). Eventually, this change in perspective and understanding of the depth and complexity of instructional planning could lead to better performance and increased intrinsic motivation related to the task.

The presence of the constructivist agent tended to change participant perspective toward instructional planning. Even though participants previously had been introduced to the constructivist approach, they may have experienced it as a novel approach that provided more options for instructional planning, especially in contrast to the traditional instructional approaches that most had personally experienced as students. Further, they may have perceived the presence of the constructivist pedagogical agent as highlighting more appealing elements of instructional planning (such as a student-centered rather than teacher-directed focus, or highlighting the responsibility of the learner). An alternative explanation is that as the characteristics inherent to the constructivist pedagogy itself (e.g., fostering awareness, reflection, and critical thinking) were applied to the case study of Anna, they indirectly impacted the participants' own metacognitive awareness, reflection and critical thinking regarding planning. In this way, the constructivist agent may have facilitated the preservice teachers in thinking reflexively (i.e., by being aware of how and what knowledge creates meaning for them, Driscoll, 2000) about their personal choice of instructional approach. Here, reflexive thinking refers to their personal beliefs about selecting a meaningful instructional approach, and differs from the content-specific reflection they engaged in while developing the instructional plan within MIMIC. Through this reflexivity, they may have come to realize how the constructivist instructional approach and its correspond-

ing epistemological perspective shaped their understandings of planning instruction. Qualitative data suggest that these participants attributed the change in perspective to the realization and appreciation of the difficulty of instructional planning and the new ideas provided, thus supporting the previous explanations.

While the two-agent condition was more transforming than the instructivist-only and no-agent conditions, it did not lead to the greatest change in perspective, as had been predicted. The fact that the presence of two agents simultaneously was not perceived as the most transforming in terms of a change in perspective could be an issue of cognitive load. As Sweller, van Merriënboer, and Paas suggest (1998), "less is best" in learning situations, indicating that in this case the learners may be too focused during problem solving to process advisements from multiple agents.

The finding that the presence of the constructivist agent led to less reflection seems at first incompatible with the finding that the constructivist agent led to a greater change in perspective. However, when the constructivist agent was present, perhaps participants were focusing their attention on its ideas and suggestions rather than reflecting on their own cognitive processes. In other words, it seems viable that the presence of the constructivist agent facilitated preservice teachers to *think* more (i.e., change perspective), but not necessarily to *reflect* more. While there is strong evidence that reflection during instructional activities is important (Chi & VanLehn, 1991; VanLehn, Jones, & Chi, 1992), there is less information regarding the relative value of reflection as compared to metacognitive awareness.

The presence of the constructivist agent was also associated with participants' developing more constructivist-oriented instructional plans, reflecting a trickle-down effect of the agent's pedagogical beliefs to the participants. There was some indication (although not statistically significant) that the presence of the instructivist agent may have been related to more instructivist-oriented underlying pedagogy in participants' instructional plans. Thus, in both cases (instructivist and constructivist agents) the preservice teachers appeared to internalize the agent's advisements and translate them within their instructional plans.

There were no overall positive effects of the agents on attitude. Perhaps the agents in MIMIC did not significantly impact attitude because their purpose was to represent different perspectives rather than to provide specific support to improve performance. Along this line, other cognitive tools for supporting instructional planning that improved attitude also improved performance (Baylor & Kitsantas, 2001a, 2001b; Kitsantas & Baylor, 2001).

Contrary to what was hypothesized, the presence of the instructivist agent led participants to report significantly *lower* dispositions toward instructional planning. Given that the instructivist agent represents a systematic approach, perhaps students felt it was too prescriptive, and were thereby more likely to think that it made the instruction and planning process seem less engaging. As described in Kitsantas and Baylor (2001), many preservice teachers describe traditional instructional planning as "time consuming" and "tedious."

There were no main effects of the agents' presence on the overall performance score. The absence of such effects is supported by Dehn and van Mulken's (2000) review of empirical research that found that the use of animated agents does not generally contribute to improved performance. While more recent research investigations have found positive effects on performance in educationally-based uses of animated pedagogical agents (Atkinson, in press; Moreno et al., 2001), the agents were implemented in well-structured content domains (math and science) and were not designed to represent different instructional roles or perspectives. The MIMIC agents provided content-specific advisements regarding the underlying pedagogic rationale for different aspects of the planning process, not prescriptive advice or solutions. Given that the performance measures were based on the instructional plan created by participants *within* MIMIC, perhaps different posttest measures of near and far transfer of learning would be more appropriate and yield a greater probability of significant results.

In terms of the role of achievement level, it

was of interest that low performers tended to change perspective more than did high performers, regardless of treatment condition. Perhaps the low performers were less accustomed to finding success and positive affect in school tasks (Kagan, 1990), and were intrigued by the fantasy, novelty, sociability, and power associated with instructional planning. Alternatively, their low performance could be an indication of their lack of prior assimilation of the approaches; thus, they were more likely to have a change in perspective when confronted with them again in MIMIC. Qualitative data show that as a result of MIMIC the low performers were much more likely to realize the difficulty of instructional planning, which supports their change in metacognitive awareness. The additional finding that high performers developed significantly more constructivist plans than low performers indicates that they were versatile in incorporating the constructivist ideas even while they tended to report "thinking" more like the instructivist agent than did the low performers. This flexibility in the instructional planning approach is characteristic of more skilled instructional planners (Perez & Emery, 1995; Rowland, 1992). Given that the analysis of high and low performers was exploratory in nature, further research should be conducted to confirm these findings.

Overall, the present study provides preliminary evidence to suggest that the exposure to the constructivist approach adds richness, diversity, meaning, and interest to the process. The fact that the best performers were significantly more likely to report "thinking more like the instructivist" (i.e., more systematically and structured) than the low performers indicates the probable link of instructivism to traditionally assessed performance. Yet while the instructivist approach adds substance and structure to the process, it may negatively affect disposition, which is cause for concern, given its potential for facilitating the development of effective instructional plans (Reiser & Dick, 1996). One promising tool to address this issue of negative disposition toward traditional instructional planning is the Instructional Planning Self-reflective Tool (Baylor, Kitsantas, & Chung, 2001), which has been found to positively impact disposition (Kitsantas & Baylor, 2001).

Future research could include a more extensive epistemology profile to determine if preservice teachers' epistemic beliefs change as a result of using the system. The role of reflection needs to be further investigated through open-ended questions and by systematically evaluating the agents' self-regulatory features to determine how they relate to what the participant terms *reflection*. Cognitive load as an explanation for the impact of two agents could be further investigated with more advanced students, who may be able to better manage receiving advisements from multiple agents.

Overall, this study validated the effectiveness of an agent-based approach as a research process to investigate teaching and learning (Baylor, 2002). Further, this study provides preliminary evidence that agent-based learning environments can facilitate the promotion of metacognitive awareness through pedagogical agents serving different instructional roles, thus, contributing to our growing understanding of learning outcomes in complex interactive environments. □

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