Design and usability assessment of a dialogue-based cognitive tutoring system to model expert problem solving in research design

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Abstract
Technology provides the means to create useful learning and practice environments for learners. Well-designed cognitive tutor systems, for example, can provide appropriate learning environments that feature cognitive supports (i.e., scaffolding) for students to increase their procedural knowledge. The purpose of this study was to conduct a series of usability tests of a dialogue-based design framework for the presentation of domain knowledge and assess how it can be used to actively engage learners in learning about research methods. Three formal usability assessments and an instructor adoption assessment were conducted during the development of the tutoring system. Each usability assessment employed diverse data collection methods to ensure broad and in-depth coverage of findings. The findings revealed that the dialogue metaphor enabled natural and participatory interactions between the system and users. The feedback prompts or hints and support resources provided opportunities for learning during the process of problem solving. Future research to extend the support of usability assessments is also discussed.

Introduction
The increased power and flexibility of computer technology is contributing to renewed interest in cognitive tutoring systems for use in educational environments. This development coincides with current perspectives on effective instruction in which meaningful learning depends on the construction of knowledge by the learner (Bransford & Schwartz, 1999; Chi & VanLehn, 2012; Goldstone & Day, 2012). When a cognitive tutoring system is designed to support learners in the exploration of knowledge objects, it provides flexibility and interactivity allowing them to reflect upon and model the utility of knowledge in a given subject (Arnot, Hasting & Allbritton, 2008; Graesser, Person & Magliano, 1995; Mathan & Koedinger, 2005). Moreover, when a cognitive tutoring system is used in higher-order learning activities, such as problem solving and decision making, it has the potential to facilitate development of learners’ mental models of complex situations as well as their problem-solving strategies (Dekkers & Donatti, 1981; Lane & VanLehn, 2005).
The design approach of cognitive tutoring systems typically involves a problem-solving exercise expressed through a series of carefully scaffold scenarios. The goal is to provide learners with needed scaffolds and regulation as they attempt to solve a complex problem or task. Scaffolds allow learners to seek guidance (e.g., through prompts) and feedback whenever they attempt to generate appropriate actions towards problem solutions. Regulation involves those features that allow learners to self-monitor and self-correct their performance (e.g., progress maps, performance monitoring and growth charts). A number of studies have suggested that the incorporation of scaffolding and regulation strategies in cognitive tutoring systems play a significant role in improving student learning. Athinson, Renky and Merrill (2003) reported that feedback and metacognitive prompts allow authentic problem solving in classrooms, and the results can be immediately observed. Lim, Lee and Grabowski (2009) found that, in knowledge and skill acquisition, computer-based training enhances student interest beyond that of traditional lectures. In addition, empirical evidence suggests that the self-paced and problem-solving features provided in cognitive tutoring systems enrich the learning environment (Cruickshank & Olander, 2002; de Vries, Lund & Baker, 2002; Koedinger & Alevin, 2007; Sandi-Urena, Cooper & Stevens, 2011). Arnott et al (2008), in a study involving nursing practice, observed that incorporation of guided exploration in cognitive tutoring systems promotes deep learning.

Although cognitive tutoring systems provide opportunities for enhanced learning through guided instruction, learners must be sufficiently self-motivated and able to adapt to the computer interface to be successful. Learners must navigate the system, utilize various functions, such as glossaries, guided maps, help tools, delayed or immediate feedback, and also monitor their learning performance (Mayer & Moreno, 2003). The effectiveness of cognitive tutoring systems can be hampered by minimal user interactions with the content materials. This deleterious effect can result from learners being placed in a prescribed learning environment where content is presented in a linear rather than holistic form. In this linear format, interaction with content is typically limited to a question and feedback loop. Learner interest in the subject matter may decline because of the repetitiveness of such a system.

The present study proposes an alternative framework to address design issues often observed in cognitive tutoring systems. The system designed in this study, REsearchMentor, uses a dialogue approach.
metaphor framework with visual representations (Language Development and Hypermedia Research Group, 1992) to provide support for learners as they work through a sequence of problem scenarios. The purpose of the present study was to assess the usability of this dialogue-based tutorial, which was designed to facilitate the development of students’ knowledge in social science research methods. Additionally, we were interested in examining students’ perceptions of the system.

**Design framework of REsearchMentor**

REsearchMentor was inspired, in part, by the work of J.R. Anderson and colleagues (Anderson, Conrad, & Corbett, 1989) who developed cognitive tutors in the 1980s to help high school and college students learn geometry, algebra, statistics and computer programming language. A significant aspect of Anderson et al’s work was to validate Anderson’s Adaptive Character of Thought (ACT)* theory of learning and problem solving (Anderson, 1983). REsearchMentor is neither based on ACT* (or the revised Adaptive Character of Thought-Revised) theory, however, nor have we developed the cognitive tutor in the same manner as Anderson et al. Our initiative was driven by pedagogical rather than theoretical concerns. That is, we wanted to develop a cognitive tutor that supplements but does not replace live instruction, supports and reinforces students’ learning, and provides enjoyable learning experiences for students, thereby enhancing their motivation to learn research methodology and ensuring that they will use the tutor.

In developing REsearchMentor, content is embedded in a problem-based scenario represented through a series of illustrated dialogues between characters. The dialogue is structured to model closely an expert approach to planning and designing social science research projects. This design approach allowed us to create a virtual environment for learners that address “real-life” research situations. The system employs multimodal content delivery methods. Problem-solving activities for students pertain to the conceptualization, planning and design of a research study appropriate for the behavioral and/or social sciences. Cognitive scaffolding strategies incorporated within the dialogue sequence (eg, queries, hints, prompts and examples) anchor students’ learning and lead them towards correct responses. Other scaffolds include definitions of terms and constructs provided in a glossary and audiovisual presentations of research concepts such as sampling. The overall design goal was to situate expert reasoning in authentic scenarios to provide relevant learning experiences and promote high engagement among learners (Jonassen & Hernandez-Serrano, 2002; Paulus, Horvitz & Shi, 2006; Polkinghorne, 1988).

The content embedded in REsearchMentor was neither intended to be exhaustive of the social science research methodology domain nor did it (at least in its current form) address complex situations and/or techniques that more experienced researchers might encounter or employ to conduct research. Rather, the content of REsearchMentor was designed to introduce basic concepts of research design that a student or novice researcher might encounter and use. The content elements include the phrasing of simple research questions (using the language of group differences, intervention effects and relationships), identification of classes of variables (independent, moderator, dependent), operational definitions of constructs, selection of appropriate sources for a literature review, determination of a research design suitable for addressing the research question, selection of a sample and the use of random assignment, determination of appropriate data analysis techniques, and consideration of ethical issues involved with research. To illustrate how REsearchMentor supports learner problem solving and sustains motivation through the use of a dialogue metaphor, screen captures of the system are presented and explained below.

To use REsearchMentor, the user (eg, instructor, researcher or student) logs in to the system and creates a username and a password (see Figure 1). Logging in enables storage of user responses
in a system folder. Next, the user is presented with an introductory screen that describes REsearchMentor and prepares the user for the simulated task that follows.

As the user begins the simulation, a research scenario is presented in which two animated characters (Devon and Juan) describe the context and goals of a specific research problem they want to address and resolve. Devon and Juan then appear as animated figures, and a conversation ensues between them (in both audio and textual form). After listening to and viewing each animated scene in the sequence, the “mentor,” Seymour, prompts users with several possible responses (see Figure 2).

Users are then prompted to select what they judge to be the correct or most appropriate response to the supplied prompt. Seymour provides reinforcing feedback if the learner selects an appropriate response option, and provides corrective feedback and helpful suggestions if the learner specifies an inappropriate option (whereby he/she is prompted to try again).

As each scenario progresses, the learner is presented with additional information about the research problem along with relevant queries. For example, at one stage in the scenario, Seymour informs the users that Juan and Devon want to conduct an intervention study with treatment and control groups, and administer an instrument to measure students’ interest in science. Subsequent queries ask how Juan and Devon might select a sample and how these participants should
be assigned to treatment and control groups. Additional queries address sample size and design strategies that can increase the internal validity of the study (eg, using both a pretest and a posttest).

A number of scaffolding, guidance and tutorial features are embedded within the scenario to assist users when they encounter difficulty and require guidance. These include (1) a glossary to familiarize users with key terms used in research, (2) a communication function that enables students to submit questions or research design ideas to the research course instructor for comments and feedback, (3) brief audio and visual tutorials or “mini lectures” on research topics relevant to the scenario that are presented and (4) a performance review widget that indicates the user’s progress and performance as determined by responses to the simulation queries. Figure 3 shows screenshots of scaffolding, guidance and tutorial features embedded within the scenario.

REsearchMentor’s contents align well with the essential contents that are taught in many introductory-level social science research courses. Thus, the tutor can be utilized to both instruct and reinforce students’ learning of essential research concepts. It can be used flexibly by instructors to supplement lectures and engage students in class discussions about research problems or be used for small-group research projects. Our research and development team is planning to elaborate and expand upon the research scenario that has been created. New scenarios will include a variety of research problems and questions from different social sciences fields (ie, psychology), and the scenarios will feature diverse characters (see Figure 4).

Individualized instruction such as online learning system, cognitive tutors and e-book could become the dominant form of teaching and learning for education. Although it is doubtful that such system would ever replace the traditional educational institutions, individualized instruction will likely continue to expand and does provide the opportunity for the development of better designed learning environments within higher education.

**Usability assessment of REsearchMentor**

A user-centered design process was used to assess the usability of REsearchMentor. This approach integrates design, data collection and evaluation in a continuous process. In this feedback loop approach, users are involved throughout the development of the tutorial system. This approach is an essential aspect of human computer interaction processes used to improve tutor systems (eg, Booth, 1989; Rogers, Sharp & Preece, 2011). A system design process is user-centered to the extent that it addresses “user-relevant issues at all stages in whatever form is appropriate”
Specifically, we were interested in learning if users could readily navigate Experimental Mentor’s design features and tools, understand the tutorial scenario and respond appropriately to the system features.

Data collection and instrumentation

Three formal usability assessments were conducted throughout the development of Experimental Mentor: (1) usability assessment of system architecture, (2) usability assessment of system content and (3) usability assessment of potential system implementation. Each usability assessment employed varied data collection methods to ensure broad and in-depth coverage of findings. Determination of sample size for each usability assessment was based on Dumas and Redish’s (1999) usability guidelines, which recommend 5–12 participants to attain reliable usability information to validate a software system.

In addition to the usability assessments, an instructor adoption assessment was conducted to evaluate user acceptance of Experimental Mentor. The purpose and procedure associated with each assessment are described below.

Usability assessment 1: system architecture

A two-step assessment approach was used to uncover any usability issues related to system architecture, including interface, navigation and orientation. A total of 15 first- and second-year graduate students were recruited to participate in these two steps of the assessment. Of these 15 students, three second-year students participated in the first step, which involved video recorded think-aloud sessions in a controlled setting to closely monitor how users interact with the system. Once the system navigation and orientation structure were developed to be fairly intuitive, the remaining 12 first- and second-year students participated in the second step of the usability assessment, which involved using the system to complete a research scenario in a classroom environment where the instructor was one of the authors. Participants were provided with worksheets and asked to record their responses (e.g., technical difficulties, unclear concepts, inappropriate or irrelevant feedback, difficult or confusing navigational aids, or logical inconsistencies) as they worked through the scenario. Upon task completion, participants were asked to
orally describe their experiences using REsearchMentor. Their comments were recorded and transcribed, and the data were used to modify the system.

**Usability assessment 2: system content**

After the system architecture was tested and modified based on feedback, content assessment was evaluated using a distinct sample of participants to ensure the dialogue-style content was learnable and comprehensible. To this end, a sample of 24 graduate students was recruited and asked to complete the research scenario embedded in the dialogue. The participants were also asked to complete a “quality control” usability checklist to determine whether the system was logical and easy to comprehend. The quality control checklist contained 10 “yes/no” questions, such as “can you locate the glossary function on the toolbar?,” “can you locate and read information panel?” and “does the corrective feedback provided make sense to you?” The participants completed the checklist items as they progressed through the research scenario. The purpose of this assessment was to evaluate the content learnability and usability of REsearchMentor. That is, was the system easy to interact and navigate? Was it logical and easy to understand? Did the features work properly and provide helpful tools for the user? Additionally, these participants were asked to respond to an instrument that assessed their attitudes toward the REsearchMentor tutorial system. Of the 24 students, all completed the quality control checklist, whereas 22 completed the attitude assessment.

**Usability assessment 3: potential system implementation**

To better prepare the system for classroom and field implementation, a usability study to assess potential system implementation was conducted to further improve the system readiness. This study assessed user response to system features, such as mini tutorials, in addition to soliciting suggestions for additional feedback to be included, as well as suggestions for additional instructor and student resources, and ways in which the system could be used to support classroom instruction. Two focus groups were conducted for this purpose. Participants in these focus groups were a nonprobabilistic, purposeful sample of 14 students drawn (eight in one focus group, six in the other) from a single educational research statistics course at a major Midwestern public university. Participants received a brief description of the study. None of the focus group participants had prior experience with REsearchMentor.

Each focus group lasted for a duration of approximately 45 minutes, and participants’ responses to a prespecified set of queries were recorded. These queries included “does REsearchMentor allow you to reflect on your ability to do research?,” “are you able to form a mental map of the research problems in terms of the relationship between variables, measurement of variables, and the intended or expected outcomes of the research when you use REsearchMentor?,” “what are the major problems you experienced with REsearchMentor, and how might these problems be addressed?,” “in your opinion, what are the best ways to use REsearchMentor?” and “what are your suggestions for using REsearchMentor in educational settings?” Data from the focus group were coded for key terms by two evaluators, and these key terms were then aggregated into themes.

**Instructor adoption assessment**

An additional usability assessment was conducted by a group of faculty members (n = 5) who were identified as instructors who could potentially implement REsearchMentor in their classes. The purpose of this assessment was to identify appropriateness of the content as well as to identify ways in which REsearchMentor could be utilized as a support tool in educational research method courses. All five instructors were tenured or tenure-track faculty members who had taught research method courses on a regular basis in programs such as child and family studies, rehabilitation counseling, sociology and educational technology. Each faculty participant was asked
to review the functions and research scenarios of REsearchMentor and then complete a rating worksheet related to adoption of REsearchMentor as a support tool in his/her research method courses. The instructor feedback sessions were intended as the final usability assessment prior to implementation of the system into actual courses. Feedback collected was used to aid in the development of an instructor guide as well as to revise the content of the system.

Results
Results related to each usability assessment, and the instructor feedback assessment, are reported along with discussion of design implications.

Results of usability assessment 1: system architecture
The purpose of this usability assessment was to uncover any usability issue related to system architecture, including interface, navigation and orientation. Several themes emerged from the qualitative data collected from the first- and second-tier usability assessments. These included dialogue and metaphor, system interface, system interaction, and content (Table 1). Exemplars of these themes included both aspects that users appreciated/enjoyed (eg, step-by-step sequencing of the dialogue) as well as areas needing improvement (eg, need to switch between mouse and keyboard to advance the scenario).

Overall, the testers had positive responses to the system. Specifically, they felt that the dialogue was easy to follow, and the question prompts instilled a sense of active participation. The interaction and feedback provided adequate information to inform their actions. The screen layout was legible and promoted awareness of features that were embedded in each system function. The inadequate help provided by the “mentor” (Seymour), however, prevented them from further exploring the system in depth. Several testers reported feeling insecure about their control or were “lost” during their interaction with the system. This feeling of insecurity occurred when performing particular in-depth tasks including exploration of mini tutorials, restart of scenarios and note taking. The usability assessment and the informal evaluation conducted after creation of the system prototype were primarily focused on the interface design and system structure. At the next stage of usability assessment, the question prompts and content appropriateness were evaluated.

Results of usability assessment 2: system content
The purpose of this usability assessment was to ensure that the dialogue-style content and question prompts were learnable and comprehensible. When the completed usability checklists were tallied, results showed that greater than 90% of the 24 participants were able to successfully complete the assigned usability tasks for nine of the 10 assigned tasks. Table 2 shows responses to each of the items on the usability checklist. The one task that was difficult for participants involved successfully advancing through the research scenario to its conclusion. This occurred because some participants were unable to respond to the prompts correctly, and at some point, they stopped trying. This problem was addressed by revising the dialogue and feedback prompts provided by the mentor to include more explicit instruction.

Upon completion of the usability assessment, the 24 participants in the system content usability assessment were invited to complete a survey assessing their attitude towards REsearchMentor. Of the 24 students, 22 completed the survey. Table 3 summarizes the distribution of respondents’ responses. Overall, results indicated that participants had positive perceptions of REsearchMentor, with particularly strong impressions of the system’s ability to support comprehension of concept of research questions and definitions of research design. Additionally, a majority of respondents (91%) agreed or strongly agreed that the research scenario provided was about the right length.

Results of usability assessment 3: potential system implementation
In this usability assessment, two focus groups (consisting of six and eight participants respectively; with combined n = 14) were conducted to discuss usage, constraints and application of
Table 1: Themes and exemplar statements from the think-aloud study

<table>
<thead>
<tr>
<th>Themes</th>
<th>Exemplars</th>
<th>Revision approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dialogue metaphor</td>
<td>Testers mentioned problems with the bubble dialogue related to the positioning and sequencing of the bubble dialogues. One of the testers preferred to see both Juan and Devon’s dialogues at the same time when being prompted to select the best answer. Testers also suggested giving Juan and Devon name badges or doing something to make identifying the characters more clear. Testers mentioned that they liked the step-by-step progression that the program follows.</td>
<td></td>
</tr>
<tr>
<td>System interface (screen layout, navigation bar, menu and buttons)</td>
<td>Testers mentioned that there were many elements competing for their attention on the screen. Testers also said that the progress bar should provide additional information such as number of questions of concepts to be interacted. A few testers skipped exploration of on-screen video tutorials and note taking features because of lack of uncertainty.</td>
<td></td>
</tr>
<tr>
<td>System interaction</td>
<td>Testers had no problems interacting with the system but did not like switching between the mouse and the keyboard to interact with the system.</td>
<td>1. Implemented widget-like panels to organize information and interface to maintain consistent content presentation</td>
</tr>
<tr>
<td>Content (readability, sequence and comprehension)</td>
<td>Testers said that REsearchMentor is a good way to reinforce and refresh prior knowledge. Testers also believed that REsearchMentor would be useful as a self-study system outside of the classroom.</td>
<td>2. Reorganized system add-ons (tutorial, note taking, glossary) to a widget panel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Use different shades of color to highlight or fade interface elements to guide learners’ visual movement (Thissen &amp; Rager, 2011)</td>
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<td></td>
<td></td>
<td>4. Provided textual feedback in the progress bar and performance meter</td>
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<tr>
<td></td>
<td></td>
<td>Made both types of interaction available—learners can interact with the system using mouse and/or keyboard.</td>
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<tr>
<td></td>
<td></td>
<td>The authors also incorporated additional content (question prompts) and tutorials to enhance REsearchMentor as a possible supplementary tool for instructors to use in classroom.</td>
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</table>

Table 2: Frequency distribution of responses for the usability checklist (n = 24)

<table>
<thead>
<tr>
<th>Task</th>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can you register/log in to the system?</td>
<td>23</td>
<td>96</td>
</tr>
<tr>
<td>Can you locate the note-taking function on the toolbar?</td>
<td>23</td>
<td>96</td>
</tr>
<tr>
<td>Can you locate the glossary function on the toolbar?</td>
<td>23</td>
<td>96</td>
</tr>
<tr>
<td>Can you locate and read information panel?</td>
<td>22</td>
<td>92</td>
</tr>
<tr>
<td>Can you locate the learning outcomes on the screen?</td>
<td>22</td>
<td>92</td>
</tr>
<tr>
<td>Can you move back to the previous screen?</td>
<td>23</td>
<td>96</td>
</tr>
<tr>
<td>Can you locate the instruction panel on the screen?</td>
<td>22</td>
<td>92</td>
</tr>
<tr>
<td>Does the feedback provided make sense to you?</td>
<td>23</td>
<td>96</td>
</tr>
<tr>
<td>Does the corrective feedback provided make sense to you?</td>
<td>23</td>
<td>96</td>
</tr>
<tr>
<td>Were you able to continue advancing through the screen to the end of the scenario?</td>
<td>21</td>
<td>88</td>
</tr>
</tbody>
</table>

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REsearchMentor. One session was conducted by the primary author, and another session was led by the second author. Each session lasted 30–50 minutes. Prior to the focus group sessions, participants were provided an opportunity to use REsearchMentor and complete the research scenario. Three primary themes emerged from the data. These themes, together with exemplar narrative from the focus groups, are shown in Table 4.

Overall, participants confirmed that the use of dialogue metaphor and question prompts together with the mentor feedback provided them with a reflective learning space where they could experience and reflect on how a research study is constructed. The system’s scaffolding and modeling features were indicated as reasons for this as they offered guided inquiry support for the learners to observe an expert’s practices.

Instructor adoption assessment
Results of the instructor adoption assessment indicated that faculty participants were positive about the system’s usefulness as an online learning tutor for students, and they were interested in using it in their research method courses. Most faculty participants agreed that the system could be used as an exercise to reinforce course lectures and to model expert thinking regarding how to carry out research design. They also agreed that the system’s question prompts provided a moderate degree of difficulty for a typical student. Table 5 provides a summary of responses to the course adoption assessment.

Discussion
The results of usability assessments support our design approach wherein a dialogue metaphor provided critical features that supported participants in solving research design problems. The
thought processes were supported as the participants actively entered into the mediated dialogue environment. The learner refined his/her knowledge by responding to prompts throughout the dialogue—following a step-by-step progression towards solving design problems. In addition to examining the effectiveness of the dialogue metaphor used in the system, other design attributes, such as mentor feedback or hints, and supportive resources (e.g., mini tutorials and glossary) were also assessed as potential supports for participants’ problem solving. It was clear that these design attributes were helpful to the participants and often provided timely support to meet their needs. The participants were able to explore the functions that were most suitable for their needs when they interacted with the system. Furthermore, the amount of content and feedback was relevant and concise enough to meet their needs.

Based on the findings from focus groups, REsearchMentor enables participants to receive expert feedback on two important aspects of research design: prediction and intervention. It enables participants to explore how different factors and variables influence an outcome or understanding of the most appropriate predictors for a given outcome. It also enables participants to differentiate ways of recognizing utilization of an intervention to test a hypothesis or explanation. The data from focus groups also revealed that a cognitive tutoring system, such as REsearchMentor, has the potential to facilitate participants’ metacognitive processes. The prompts provided by the mentor and dialogue characters created an environment that constantly engages participant to reflect on their own thinking and make adjustments towards solutions. These findings on dialogue-based feedback are similar to studies conducted by Arnott et al. (2008) and VanLehn et al. (2007), suggesting that specificity of content provided in feedback facilitates learning. When feedback is specific to users’ response and has intrinsic value, it motivates users to inquire further with the issue under investigation (Roll, Aleven, McLaren & Koedinger, 2011). However, unlike the computerized feedback (i.e., feedback based on naturalistic programming language), REsearchMentor uses predefined answers (list of choices) and feedback to guide the

<table>
<thead>
<tr>
<th>Theme</th>
<th>Exemplars</th>
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<tbody>
<tr>
<td>Theme 1: providing structure and guidance to help users recognize various constructs of research design and understand how these constructs can be applied in a real world setting</td>
<td>“It helped narrowly define what I was looking to achieve by prompting me with questions that I never thought about asking.”</td>
</tr>
<tr>
<td></td>
<td>“Tells you how to break down your variables into categories.”</td>
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<tr>
<td></td>
<td>“I felt like I was definitely on a level that I could work at.”</td>
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<tr>
<td></td>
<td>“. . . it helped keep your focus on that specific population.”</td>
</tr>
<tr>
<td>Theme 2: providing a procedure for designing research similar to one that would be used by an expert; users can then model appropriate ways of developing good research designs.</td>
<td>“I like that it had the ethics thing at the end. People don’t always do.”</td>
</tr>
<tr>
<td></td>
<td>“I liked the differentiations that it helped make like between experimental designs and non-experimental designs as it goes through and it’s asking does it fit this criteria, yes or no, and just to make sure you’re on the right track. I like that.”</td>
</tr>
<tr>
<td></td>
<td>“The variables help you kind of address and support what you have to come up with.”</td>
</tr>
<tr>
<td></td>
<td>“It really helped you to, to really zone in on the population because you already have so many things reeling through your head.”</td>
</tr>
<tr>
<td></td>
<td>“Getting you thinking about what your variable is, how to phrase your question, what are you looking to measure.”</td>
</tr>
<tr>
<td></td>
<td>“I think making you think about things you didn’t think about before. Like instead of just saying your variables, defining them.”</td>
</tr>
<tr>
<td></td>
<td>“It reminds you to have a specific population for your target. So it was really a helpful guide.”</td>
</tr>
</tbody>
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users through a step-by-step progression towards solving design problems. This guided design approach may give novice learners a sense of control over their learning as they are not required to respond to open-ended questions that may cause frustration or confusion (D’Mello, Lehman & Person, 2010; Graesser et al., 2008). This is evident in our usability test in that 78% of participants judged the system to be engaging and interesting. However, further studies should be conducted to fully understand the relationship between user performance and emotions when interacting with a well-guided tutoring system like REsearchMentor.

Additionally, as REsearchMentor is intended to supplement rather than replace live instruction, its design approach may be expanded for learning of and collaboration on ill-defined problem-solving tasks. With the use of predefined choices and feedback, a scenario with multiple possible outcomes and guided prompts can be created and integrated to support development of complex problem-solving skills. This also creates opportunities for learners to collaboratively or individually apply and evaluate the knowledge they have acquired from the live instruction. For example, a scenario can revolve around a research problem about examining the effects of using serious

Table 5: Frequency distribution of responses to instructor adoption assessment (n = 5)

<table>
<thead>
<tr>
<th>Item</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How useful would REsearchMentor be as an online learning tutor for students in research method course(s) that you teach (or have taught)?</td>
<td>N/A Very limited Somewhat useful Highly useful</td>
</tr>
<tr>
<td>2. How likely is it that you would adopt an online learning tutor such as REsearchMentor in research method course(s) that you teach (or could teach)?</td>
<td>N/A Very limited Somewhat useful Highly useful</td>
</tr>
<tr>
<td>3. How would you use REsearchMentor in your research method courses?</td>
<td>Yes No</td>
</tr>
<tr>
<td>Assigned activity</td>
<td>3 (60%) 2 (40%)</td>
</tr>
<tr>
<td>Extra credit activity</td>
<td>3 (60%) 2 (40%)</td>
</tr>
<tr>
<td>Exercise to reinforce lecture</td>
<td>5 (100%) 0 (0%)</td>
</tr>
<tr>
<td>Model thinking for students</td>
<td>4 (80%) 1 (20%)</td>
</tr>
<tr>
<td>Collaboration or group work</td>
<td>1 (20%) 4 (80%)</td>
</tr>
<tr>
<td>4. Rate the degree of difficulty of REsearchMentor’s multiple-choice questions for your typical students.</td>
<td>Very easy Easy Difficult Highly difficult</td>
</tr>
<tr>
<td>5. Rate the complexity of the research scenario problem for your typical students.</td>
<td>Very simple Simple Complex Highly complex</td>
</tr>
<tr>
<td>6. Rate the helpfulness of the hints provided for answering questions.</td>
<td>Not helpful A little helpful Helpful Very helpful</td>
</tr>
<tr>
<td>7. How useful do you think that this online learning tool is for students to learn about research methods?</td>
<td>Not useful Limited usefulness Somewhat useful Highly useful</td>
</tr>
</tbody>
</table>

N/A, not applicable.
games to promote students’ interests in science. The dialogue can take place among the teacher, researcher and game designer who are interested in the study of how students react to the games and how does learning take place. Each set of dialogue can raise a different research focus, such as behavioral changes resulting from game playing or actions taken to further learners’ understanding of the science content. Corresponding prompts and feedback can then be provided to help learners understand how and what research design should be considered to achieve desirable outcomes.

By allowing learners to apply and reflect on different design approaches, the tutor creates a learning environment that has the potential to support learners’ ability to make meaningful connections to the instructional learning goals (Collins, Brown & Holum, 1991; Kolodner, 2006; Weiss, 2003). The findings from both focus groups showed some initial signs of such expandability in REsearchMentor. As participants indicated, the system provided them with an environment that facilitates thinking, idea generalization and concept clarification. Such findings warrant further development and expansion of REsearchMentor and study of its impact, ie, to what extent can the system foster critical thinking and complex problem solving. It is also important to realize that the present study involved participants from a single subject area (education). Usability of the system could differ among users from other fields of study, and this is a potential area for further exploration.

Another area of investigation that can be further explored is the system’s relation between the visual driven dialogue metaphor, and learners’ motivation and cognitive load. Studies have shown that visualization is effective in understanding high cognitive load concepts through content organization and illustration of hidden meanings (Arcavi, 2003; Ayres, 2006; Winstead, 2004). Winstead (2004) further claimed that problems using images can tie seemingly unconnected concepts together and reveal their underlying organization. Studies have also indicated that content perceived as too complex for learners will decrease their motivation to learn (Paas, Tuovinen, van Merriënboer & Darabi, 2005; van Merriënboer & Sweller, 2005). Learners with low motivation may not persist in a learning activity long enough to engage in content mastery, and thereby, their cognitive load for the subsequent learning is increased. Based on findings from the usability tests, REsearchMentor provided a learning setting that engages participants in a mediated dialogue environment. The dialogue metaphor helped participants focused on the tasks at hand with minimum user control while keeping them engaged in seeing how the interactions between characters unfold. Such metaphors could be used to control high cognitive loads by reducing the apparent complexity of the content presented. The assumption is that the mastery of new content knowledge builds the complexity of the learner’s schemata, thereby reducing the cognitive load and enhancing confidence and motivation.

Furthermore, the dialogue metaphor extends the use of visualization by adding narratives in the form of problem to create a sense of meaning making (Bruner, 1990; Fisher, 1987). In this instance, content knowledge such as facts, principles and rules are organized into plot structures, providing for more experiential awareness and relevant learning activity than for typical instruction (ie, lecture). Together with the added narratives in a visual-oriented plot or problem, dialogue metaphors may require less cognitive effort than typical instruction as human minds relate to stories more easily and meaningfully than to expositional types of content information. A future study on the dialogue metaphor and its relation to cognitive load would help designers and researchers understand how dialogue metaphors result in learner confidence and motivation to learn.

Conclusions
The present study employed user-centered usability assessments to enable development and refinement of a cognitive tutoring system, REsearchMentor. The goal was to evaluate how effectively the
dialogue metaphor design concept, user interface, content and feedback were integrated and also
to evaluate users’ (eg, students, researchers, instructors) feedback on the system. Our research
findings helped us explore if there is a match between this novel approach and user needs, as well
as identify potential barriers from continuous use of the system. In addition, the findings also
helped us to identify the appropriateness of the instructional design strategy—a dialogue meta-
phor. REsearchMentor can be considered as an “instance” of this instructional design strategy, and
the process of usability assessment serves as a refinement for both the system and its instructional
framework (Joseph & Reigeluth, 2005).

REsearchMentor is an attempt to integrate a dialogue-based learning strategy into a cognitive
tutoring system. Our initial research goal was to test the design framework for the presentation of
domain knowledge and assess how it could be used to actively engage learners in the problem-
solving task. The findings indicated that the dialogue metaphor enabled a natural and participa-
tory interaction between the system and user. The feedback prompts or hints and support
resources provided opportunities for learning that arose during the process of problem solving.
Nonetheless, future research is warranted to augment these usability findings. Initially, field
assessment is necessary to understand how the system can be incorporated to support learning
within or outside of the classroom, as well as to compare its effectiveness with other learning
formats or media. Next, incorporation of more complex tasks into the system is needed to further
validate the design framework. Currently, the system has limited content coverage and focuses on
a very general and introductory research design approach. More complex tasks might be incor-
porated to study how the design framework can support advanced learners. For example, a
module could be created that addresses the various types of measures/instruments that could be
used to assess outcome variables. Another module might guide the learner towards selecting an
appropriate design for a study that implements covariates. Last, the dialogue metaphor should be
applied to and assessed within other content knowledge domains to study how effectively and
generalizable this design framework is in terms of its application and adaptation.

It has become apparent that the usefulness and utility of REsearchMentor lie in its ability to
support learners in a contextualized and guided environment. Development of problem-solving
skills can be cultivated through dialectical interaction. The initial usability results from potential
users and instructors have been encouraging and have implications for future work in cognitive
tutoring systems. Additional research data, together with advances in available technology, will
facilitate the evolution of this dialogue-based design approach and enhance the likelihood that it
might provide a viable educational tool.

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