Promoting learning by observing deep-level reasoning questions on quantitative physics problem solving with Andes

As e-learning environments become a standard form of instruction more learners are forced to view video examples as a substitute for interactive classroom learning. These non-interactive multimedia environment that use auditory narration to improve learning have been referred to as a vicarious learning environment (See Gholson & Craig, 2006 for review). More specifically, vicarious learning environments are multimedia environments in which the learners see and/or hear content for which they are not the addressees and have no way of physically interacting with the source of the content they are attempting to master (Craig, Sullins, Witherspoon, & Gholson, 2006; Gholson & Craig, 2006). A primary mechanism required for learning within these environments is that the learner stays cognitively active during the learning process (Chi, Hausman, & Roy, in press). In that, the learners' process incoming information so that coherent mental representations are formed and integrated into existing mental representations or schemas (Craig, et al., 2006).

The deep-level reasoning questions effect

The deep-level reasoning questions effect is one example of the impact that these narratives can have on learning from multimedia. It has long been known that question generation is one of the processing components that support comprehension (Graesser, Singer, & Trabasso, 1994; Kintsch, 1998), problem solving, and reasoning (Graesser, Baggett, & Williams, 1996; Sternberg, 1987). The Adjunct question literature also shows that forcing students to answer questions during reading will improve learning from text (Hamaker, 1986). However, in a series of two studies, Craig, et al. (2006) showed that inserting these deeper-level questions into the auditory narrative of a multimedia environment improves learning over both a narrative description without the deep-level questions and even above an interactive tutoring system, AutoTutor.

What is a deep-level question

A deep-level reasoning question is a question integrated into a narrative that scaffolds links between mechanisms, components, or processes. These questions would be analogous to the higher levels of Bloom's taxonomy and the long answer question categories from the Graesser & Person taxonomy (1994). Some examples of these types of questions are given in Table 1.

Table 1. Examples of three categories of deep-level reasoning questions. For more examples see Craig et al., 2000 or Gholson & Craig, 2006.

Causal consequence	What happens to RAM when the computer is turned off?
Goal orientation	Why was the application loaded into RAM?
Instrumental/procedural	How does the operating system open an application after you click on an icon?

Deep-level reasoning questions serve as two functions during learning. First, as discussed earlier, the deep-level questions provide scaffolded learning that help to free up mental resources so learners can process new information and build onto their existing schemas. Second, deep-level reasoning questions serve as cognitive guides (Mautone & Mayer, 2001) within the narration that help improve learning by encouraging learners to engage in a sense-making process of the material presented to them. Sense-making processes are robust learning processes wherein students try to understand the instruction or engage in higher-level thinking to create knowledge independent of instruction. This improvement is referred to as the guided learning hypothesis in the current study.

Current study

Past research with the deep-level reasoning effect have shown improved learning in the STEM areas of computer literacy (Technology; Driscoll, et al., 2003; Craig, et al., in press) and physics (Science; Gholson et al., submitted) and was applied on immediate learning measures on conceptual material. So, it is not entirely clear how

robust the learning from this effect or how the effect generalize to other types of learning. The current study investigated the deep level reasoning questions effect robust learning using the Andes homework helper (Vanlehn, et al., 2005) in the Pittsburgh science of learning center's (PSLC) Physics LearnLab at the USNA. This provided the opportunity to test this effect for long term transfer to student's homework in a Physics problem solving of Magnetism that required procedural knowledge instead of declarative.

The PSLC's Physics LearnLab consisted of two Introductory Physics course at the United States Naval Academy that currently use the Andes homework system as a part of their course. The Andes system provides introductory college level physics homework problems. Andes is not a complete tutoring system, but only a coach that helps the student solve homework problems. It functions as a workbook that provides immediate feedback and hints while students are solving problems. It encourages certain problem solving practices (e.g. drawing vectors instead of imagining them) to increase conceptual understanding of physics. Thus, the problem solving involves algebra, trigonometry and vectors, but not calculus. In this way, it is intended to be used with almost any course's textbook, lectures, and labs. The system also tracks the students progress and provides the students with an online score of the students' problem solving for each problem. Andes, also, records the score in an on-line grade book accessible by the course instructor.

Guided learning hypothesis

Previous studies (Craig et al, 2000; Driscoll et al., 2003; Craig et al. 2006) was produced because the questions served to improve the knowledge structure. So, the question served to produce a slot for upcoming knowledge components. So when a knowledge component was presented, it could easily fit into the slot provided and produce the knowledge event (Chi et al. 1994; Derry, 1996; Driscoll et al. 2003).

Methods

Participants

A total of 24 midshipmen (both male and female) from the PSLC physics LeranLab at the USNA, Annapolis were eligible to participate in this study. All midshipmen were currently enrolled in their second semester of the introductory physics course at the USNA. The study was conducted as part of their physics lab for the course. This required all midshipmen to perform the experiment, but they all had a choice of giving their consent (via an informed consent form) for their data to be used in the study and were allowed to stop their participation at any time during the study. A total of 3 participants did not give consent to use their data and were not in included in these analyses. Also, 4 other participants did not complete all experimental procedures. This left a total of 17 participants between the three conditions from the original 24 that were randomly assigned.

Materials

This study presented midshipman from the USNA recordings of worked examples for homework problems using Andes. As these problems were solved, each step was accompanied by an auditory explanation for that step. Midshipmen's Andes logs from their homework questions were examined.

The deep-level reasoning questions condition was contrasted against self-explanation and reflection conditions. The deep-level reasoning questions condition provided a deep question scaffold before each step's explanation. The self-explanation condition was chosen as a strong control condition. In this condition, midshipmen were asked to self-explain each step of the of problem solving (Chi et al., 1989; 2001). This environment would produce cognitive activity without providing the cognitive guidance of the deep-level reasoning questions. The last condition was a reflection condition where the participants watched the same video as the self explanation participants, but were only encouraged to reflect on the material.

Procedure

The midshipmen were randomly divided into the experimental conditions during a course lab session set aside for the experiment. They then filled out informed consent forms and watched two videos corresponding to their condition. This process took about 50 minutes. While participants in the self explanation group were encouraged to self explain the material in the video while it was presented to them, this experimental manipulation failed in that they did not utter self explanations. In retrospect it is not surprising these participants did not produce the self explanations since they were the only group required to produce verbal utterances. As a result, the self explanation conditions was functionally the same as the reflection condition, so these two unguided conditions were lumped together for purposes of the analysis in this study.

As part of their normal class, midshipmen then completed their homework using the Andes system. The log files from the homework on magnetism were them analyzed and coded to obtain score for overall homework score (computer automatically by Andes based on number of correct and incorrect answers and amount of help required to complete the problem) and total completion time for the homework.

Results & Discussion

T-tests were preformed on the participants' homework score data and total completion time data. The only significant difference found between groups was on the completion time data, $t(15) = 2.41$, $p<.05$. This difference was in the predicted direction of the guided learning hypothesis with participants in the deep-level questions condition completing the homework problem in 55% less time than participants in the unguided group.

While the current study provides somewhat mixed results for the effectiveness of deep-level questions in procedural domains in physics, these preliminary results are encouraging. The non-significant finding for learning could be due the small sample size for the study or to the sensitivity of the Andes scoring measure. However, the significant decrease in the amount of time required to complete problem solving during homework with the fairly small sample size suggests a fairly large effect for the deep-level reasoning questions to provide guided learning.

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