Embedded Scaffolding for Reading Comprehension in Open-Ended Narrative-Centered Learning Environments

Jonathan P. Rowe, Eleni V. Lobene, Bradford W. Mott, and James C. Lester

Department of Computer Science, North Carolina State University, Raleigh, NC 27695
{jprowe, eleni.lobene, bwmott, lester}@ncsu.edu

Abstract. Narrative-centered learning environments tightly integrate educational subject matter and interactive stories, where students serve as active participants in story-centric problem-solving scenarios. Embedding scaffolding within the storyline of a narrative-centered learning environment is a discreet approach to supporting students' learning processes without diminishing the motivational benefits of interactive narratives. This paper presents an implementation of story-embedded scaffolding in a narrative-centered learning environment, CRYSTAL ISLAND. CRYSTAL ISLAND's curricular focus has recently been expanded to include literacy education, with a focus on reading. Scaffolding takes the form of *concept matrices*, which are student-generated graphic organizers for complex informational texts that students read as part of CRYSTAL ISLAND's interactive narrative plot. Leveraging generative learning theory, we discuss directions for fading concept matrix-based scaffolding, and examine technical challenges and potential solutions.

Keywords: Narrative-centered learning environments, scaffolding, reading.

1 Introduction

There is growing evidence that narrative-centered learning environments, a class of game-based learning environments that embed educational content in interactive story scenarios, are an effective medium for fostering student learning and engagement [1–2]. A key benefit of narrative-centered learning environments is their capacity to discreetly support students' learning processes by tightly integrating educational and narrative elements. Guiding student problem solving in open-ended narrative-centered learning environments is particularly important, because students often have varying degrees of competency at solving ill-structured problems. Consequently, scaffolding in narrative-centered learning environments should meet at least two requirements: scaffolding should be dynamically tailored to individual students, and scaffolding should be naturalistically embedded within interactive narratives in order to sustain student engagement.

This paper proposes extensions to an open-ended narrative-centered learning environment, CRYSTAL ISLAND, that incorporate story-embedded scaffolding features for literacy education using generative graphic organizers. In CRYSTAL ISLAND, reading comprehension is critical for students gathering clues to solve a science

Fig 1. CRYSTAL ISLAND narrative-centered learning environment.

problem-solving mystery. Adaptively scaffolding students' reading processes is a promising direction for enhancing students' literacy skills, and has been the subject of considerable research by the intelligent tutoring systems community [3–4]. We describe how CRYSTAL ISLAND's plot and game mechanics currently incorporate story-embedded graphic organizers to scaffold students' reading comprehension processes, and outline future directions for intelligently diagnosing and fading this scaffolding.

2 CRYSTAL ISLAND for Literacy Education

Over the past several years, our lab has been developing CRYSTAL ISLAND (Fig. 1), a narrative-centered learning environment for middle school microbiology [1]. CRYSTAL ISLAND's curricular focus has recently been expanded to include literacy education based on Common Core State Standards. CRYSTAL ISLAND's narrative focuses on a spreading illness afflicting a research team on a remote island. Students act as medical detectives who must diagnose and treat the illness to save the team.

As part of CRYSTAL ISLAND's curricular focus on literacy, students encounter books and articles throughout the camp that contain complex informational texts about microbiology concepts (Fig. 2, left). Students read and analyze these texts, as well as complete associated concept matrices, to acquire knowledge to diagnose the illness. Concept matrices (Fig. 2, right) are graphic organizers, which students use to record key pieces of information encountered in the informational texts. The concept matrices are framed within the narrative as partially completed notes written by one of the research team's sick scientists. Students must discover and "complete" the notes based on content in the informational texts. The graphic organizers serve both as scaffolds for reading comprehension, as well as embedded assessments of

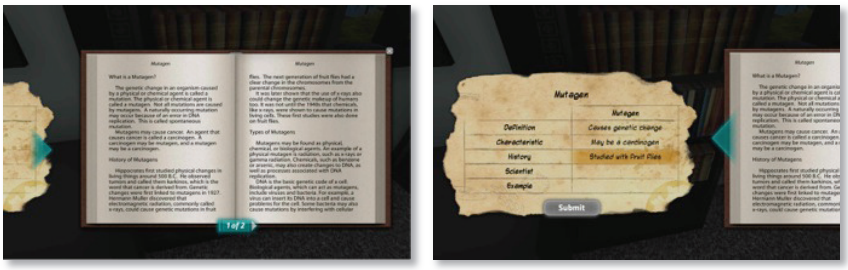

Fig 2. (Left) An informational text stylistically formatted like a virtual book, and (Right) a concept matrix stylistically formatted as a scrap of note paper.

students' reading comprehension skills. Completing a concept matrix involves clicking on each blank cell and selecting responses from drop-down menus. After a student has filled out a concept matrix, she can press an on-screen "Submit" button to receive immediate feedback on her responses.

3 Story-Embedded Scaffolding for Reading Comprehension

Graphic organizers, such as concept matrices, provide a natural mechanism for scaffolding reading comprehension skills in a non-obtrusive manner within narrative-centered learning environments. However, generative learning theory suggests that students will achieve improved learning gains if they create the concept matrices themselves. The current implementation of concept matrices in CRYSTAL ISLAND is highly structured. We plan to extend the current approach by intelligently reducing concept matrices' pre-specified structure as students improve their reading skills. Specifically, we propose fading the story-embedded scaffolding by transitioning from highly structured concept matrices to increasingly student-generated concept matrices.

Currently, whenever a student encounters a concept matrix in the story world, the matrix's layout (i.e., number of columns, number of rows) is fixed, the headings are pre-specified, and the set of possible answers for each cell are given. Fading the structure of story-embedded concept matrices can occur in at least three stages. First, one could remove the multiple-choice response menus for interior cells, instead requiring students to enter free-form text. This would require students to independently identify relationships between key terms and concepts from informational texts. Second, one could remove the pre-specified headers for each column and row, replacing them with either multiple-choice menus or free-form text entries. This would require students to independently identify the important themes in informational texts. Third, one could require students to specify the concept matrix layouts by selecting their number of columns and rows. This would require students to independently evaluate which, and how many, themes are most salient.

Effectively fading concept matrix-based scaffolding within CRYSTAL ISLAND raises notable technical challenges. The first challenge is identifying when to transition between successive levels of fading. This could be implemented as a fixed

progression (e.g., if the student has encountered *N* concept matrices, fade by one level). Alternatively, fading decisions could be based on probabilistic student models—a common practice in ITSs—although assessing student knowledge from concept matrices presents its own challenges. One could also leverage reinforcement learning to induce optimal fading policies from an exploratory corpus of student interaction data, a technique that has shown success in tutorial dialogue modeling [5].

A second challenge is automatically assessing the quality of student-generated concept matrices. Automated assessment would require models of important concepts and themes from informational texts, as well as robust techniques for comparing informational text models to student-generated concept matrices, which may suffer from spelling errors, misconceptions, and incompleteness. Third, providing feedback tailored to individual students based on their self-generated concept matrices is difficult. Feedback could concern a broad range of subjects, such as corrections of factual errors, clarifications about important themes, or suggestions for alternate layouts, and it would need to cope with students' free-form written content.

Automated assessment and feedback raise interesting computational challenges, but intermediate solutions may exist. For example, it seems plausible that one could identify constraints that good concept matrices meet (e.g., included content terms, content of rows/columns), suggesting that constraint-based models [6] may show promise. While the computational challenges are substantial, tailoring and fading generative graphic organizers to scaffold reading comprehension in open-ended narrative-centered learning environments shows considerable promise for promoting both effective and engaging literacy learning experiences.

Acknowledgments. This research was supported by the National Science Foundation under Grant DRL-0822200. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. Additional support was provided by the Bill and Melinda Gates Foundation, the William and Flora Hewlett Foundation, and EDUCAUSE.

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