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iSTART-Early: Interactive Strategy Training for Early Readers

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Abstract. In this paper, we present iSTART-Early, an intelligent tutoring system that provides automated instruction and practice on higher-order reading comprehension strategies to 3rd and 4th grade students. iSTART-Early provides personalized, interactive, game-based strategy instruction and practice on comprehension strategies (i.e., *Ask It, Reword It, Find It, Explain It,* and *Summarize It*) with grade-appropriate informational texts. Natural language processing (NLP) combined with automated speech recognition (ASR) and text-to-speech technologies enable immediate formative and summative feedback. A teacher interface allows teachers to assign texts and monitor students' performance so that they can provide additional support and feedback when necessary, creating blended-learning opportunities. We describe the interface and the development of iSTART-Early, as well as our plans to examine the intelligent tutoring system for *usability, feasibility* and *promise* in improving reading comprehension strategies and outcomes for young readers.

Keywords: ITS · Reading strategies · ASR

1 Introduction

Recognizing the promise of educational technologies for literacy instruction, developers have created computer-based learning environments to support the development of reading skills [1]. The purpose of such tools is to integrate targeted, individualized instruction into existing literacy instruction. In this context, iSTART-Early was developed to improve students' use of higher-order comprehension strategies in the service of reading comprehension, including comprehension monitoring and question asking, paraphrasing, inferencing (prediction, bridging, elaboration), explanation, and summarization.

In the average-sized classroom, it is unrealistically demanding for teachers to provide consistent and timely individualized instruction and feedback on how well students are implementing reading comprehension strategies. iSTART-Early will provide students with real-time feedback and instruction aiming to improve the use of effective

comprehension strategies. Thus, each student receives personalized instruction from the system just-in-time. Furthermore, iSTART-Early will allow teachers to adjust their classroom instruction, using student performance data in the teacher interface to inform decision making. Teachers will also be provided with additional resources and instructional materials to facilitate blended learning.

2 Technological Foundations of iSTART-Early

iSTART-Early builds and expands on the existing iSTART. The original version of iSTART showed significant improvements in comprehension and self-explanation quality in comparison to students in a control condition who self-explained the target text without prior instruction on and practice with the strategies [2]. Practice games were added to iSTART in order to increase engagement when interacting with the system over longer periods. These subsequent versions of iSTART have yielded similar gains and have increased engagement and motivation through the addition of more interactive, game-based modules [3]. iSTART has been shown to improve comprehension for middle school [4], high school [3, 5] and college students [6, 7].

In its current form for adolescent and adult students, iSTART-3, students learn the five comprehension strategies inspired from the Self-Explanation Reading Strategy Training model (SERT) [8], in addition to question-asking and summarization through video lessons, guided demonstration, and game-based practice [9, 10]. Importantly, iSTART-3 has a responsive-design, allowing for practice on desktops as well as mobile devices (e.g., tablets, cell phones).

Three major technological advances are incorporated into iSTART-Early using iSTART-3 as a foundation. The first advance is the development and increased accuracy of automated speech recognition (ASR) technology, which means that students will not need to type their responses. The second is the expansion of Natural Language Processing (NLP) algorithms and linguistic features that can accurately assess shorter phrases that are less structured or syntactically incorrect. These advances will allow iSTART-Early to provide automated reading strategy training to a younger age group (grades 3–4). Third, iSTART-Early includes options to have the text read aloud by a pedagogical agent using text-to-speech technologies. Incorporating these advances is imperative because 3rd and 4th graders need options to read the text aloud and speak their responses while learning reading comprehension strategies. Students in 3rd and 4th grades struggle with generating longer strings of text on a keyboard because they still "hunt and peck" for the letters and symbols that they need rather than typing fluently [11].

3 Core Components of iSTART-Early

3.1 Background Story and Goals

iSTART-Early is encapsulated within a meta-game, in which students participate as space travelers traveling through planets making their way back to Earth (Fig. 1). A pedagogical agent, a dog named Arfes, guides students through the five instructional planet modules.

Each planet targets one of the five major reading strategies, modified from iSTART [8]: Ask It, Reword It, Find It, Explain It, and Summarize It. Each planet includes explicit instruction in the strategies (using interacting video lessons) and engaging games that provide identification and/or generative practice opportunities. Each instructional planet is designed to build upon one another, and students must attain a certain level of performance on one planet before traveling to the next. Along their journey, students earn system currency for their performance on games and can redeem these system currencies for rewards, such as different outfits for their avatar.

Fig. 1. iSTART-Early journey map.

3.2 Lessons

A series of video lessons provide guided instruction on and demonstration of the five targeted reading strategies. Each lesson includes a video lesson that provides explicit instruction in the major strategy and its sub-strategies, in addition to embedded practice questions to ensure comprehension of the strategy and its utilization in reading.

Lesson 1: Ask It. This lesson focuses on Comprehension Monitoring and Question Asking. Comprehension monitoring is the process of being aware of one's own understanding [12–16]. This lesson teaches students how to identify detail vs. big picture questions as well as identify whether an answer to a question can be found in the text vs. needs to be answered by an outside source of information.

Lesson 2: Reword It. This lesson focuses on Paraphrasing. Paraphrasing is restating the text in different words and, preferably, in a reader's own words. It is an important part of the comprehension process because readers often paraphrase the sentence in order to begin an explanation [4]. This lesson teaches students how to paraphrase by teaching four paraphrasing sub-strategies: using synonyms, restructuring the sentence's syntax, splitting a long sentence into two, and combining two short sentences.

Lesson 3: Find It. This lesson focuses on Identifying Important Sentences in the text. Identification of main ideas is an effective strategy to improve comprehension performance [17, 18]. Indeed, explicit instruction in main idea identification and summarization was identified as one of the highest impact instructional practices that teachers can use to improve reading comprehension [19–24].

Lesson 4: Explain It. This lesson focuses on Explanation. Self-explanation is the process of explaining orally, or in writing, the meaning of written text to oneself, which can improve deep-level comprehension of content texts [25]. Explanation serves as a vehicle for students to move beyond the text and generate inferences that connect ideas in the text and background knowledge. In this context, two sub-strategies are taught, bridging and elaboration. **Bridging inferences** link ideas and the relations between separate sentences in the text. Making bridging inferences is critical to text comprehension because texts normally do not (or cannot) state all of the relevant information [26]. **Elaborative inferences** link what is in the text to related knowledge, such as individual prior knowledge, different text passages, or other outside sources of information.

Lesson 5: Summarize It. Summarization helps reduce the text to its core ideas. During summarization, readers identify irrelevant information, integrate content with pre-existing knowledge [27], and better retain text material [28]. This lesson builds upon the skills taught in previous lessons and emphasizes a number of sub-strategies, such as identifying main ideas and writing a topic sentence.

3.3 Games

Practice games were developed to increase engagement when interacting with the system over longer periods and provide opportunities for deliberate practice. In particular, we designed a series of practice games based on the space-travel theme and the main characters of the meta-game. Each game presents a unique scenario with challenges that require students to practice targeted reading strategies.

Fig. 2. Question asking game: choosing good questions for Alien students

For example, in the Question Asking game, we created a scenario where the player and Arfes (the pedagogical agent) land on a planet and visit an alien school. The principal asks Arfes to become a substitute teacher and teach alien students using an informational text (see Fig. 2). The player needs to help Arfes decide which questions are the best to deepen the alien students' understanding of the assigned text. The game provides feedback, including alien students' reactions to indicate whether or not the questions chosen by the player benefit the alien students.

3.4 Texts

The iSTART-Early team decided to focus the reading strategy instruction specifically in the context of informational, scientific texts. This decision is supported by the scarcity of access to informational texts in elementary settings [29], despite the increasing demands to include informational texts in reading curriculum [30]. Furthermore, informational texts have differing comprehension demands than narrative texts [31]. Exposure to informational texts strengthens a students' prior knowledge [32], as well as their understanding of organizational structures and text features that are not common in narrative texts [33]. The texts of iSTART-Early have been developed by professional text writers, and they received extensive reviews and fact-checking. The final corpus consists of 84 original texts, 34 of which are paired versions of different lengths.

3.5 Automated Speech Recognition (ASR)

The student interface includes ASR technology to allow students to practice reading strategies without the additional burden of typing [34]. ASR technologies have advanced remarkably in recent years, and even conventional speech recognition systems now perform satisfactorily on children's speech input. Once the students have spoken aloud their response, the ASR system transcribes their verbal responses into text. The transcribed text is filtered for frozen expressions, cuss words, or any misspelled words. The transcribed text is then presented to the student with the option to edit their response for any transcription inaccuracies (Fig. 3).
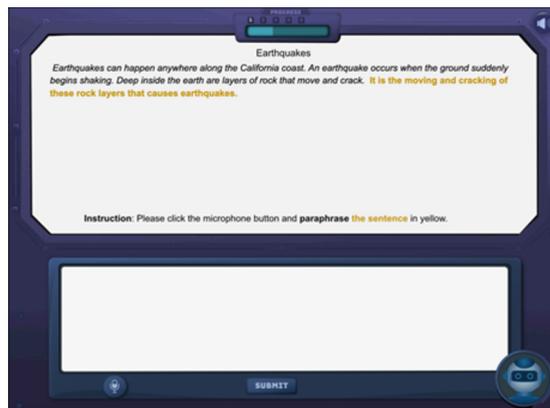

Fig. 3. ASR integration into iSTART-Early

3.6 Text-to-Speech

A text-to-speech (TTS) function has been implemented in the system to address potential difficulties with basic reading processes. TTS will read aloud full texts and difficult

words to the students. Previous research has shown that TTS improves reading fluency [35] and reading comprehension [36, 37], particularly benefiting students with reading difficulties. As illustrated in Fig. 4, when a student clicks the play button (the button in blue), the system plays the text audio from the database for the student. Students also have the capability to pause or replay the text audio. The difficult words are marked in blue to differentiate from the remaining text. A student can hover their cursor over each difficult word to learn the words' pronunciation and definition.
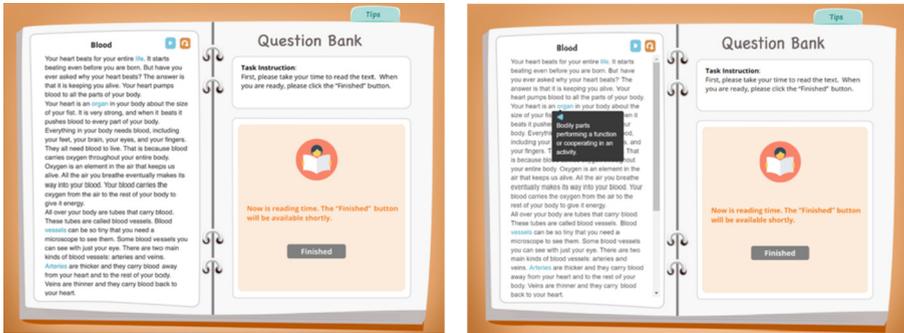

Fig. 4. Text-to-speech: full text read-aloud function (left) and difficult words read-aloud function (right panel)

3.7 Teacher Interface

The teacher interface was integrated with the iSTART-2 teacher interface [5] and allows teachers to assign students to the version of iSTART that is appropriate for their grade level. Within iSTART-Early, teachers can assign specific texts to students and add their own texts to the system library. Teachers are provided both class- and student-level data on lesson progress (including number of texts read, games played, modules completed) and reading strategy performance. The teacher interface allows for blended learning across environments, personalized instruction, and real-time feedback.

4   Conclusion

The core components and implementation features of iSTART-Early presented in this paper are designed to provide explicit instruction for comprehension strategies, with grade-level informational texts so that students can build relevant background knowledge while learning reading strategies. Build-in supports, such as ASR and TTS, are designed to address the needs of diverse and multilingual learners. Immediate feedback, gamification, and deliberate practice are designed to enhance motivation and self-regulation. Our future work will assess the usability, feasibility, and effectiveness of iSTART-Early with our target audience of 3rd and 4th grade students and teachers. Based on our initial pilot studies and prior work, we hypothesize that usable and feasible school implementation

of iSTART-Early with fidelity will improve students' reading comprehension strategy use during the reading of informational texts, and therefore improve overall reading comprehension performance.

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