IN PRESS --- PLEASE DO NOT QUOTE

iSTART: A Web-Based Tutor that Teaches Self-Explanation and Metacognitive Reading Strategies

Danielle S. McNamara

Tenaha O'Reilly

Michael Rowe

University of Memphis

Chutima Boonthum

Irwin Levinstein

Old Dominion University

Abstract

iSTART (Interactive Strategy Training for Active Reading and Thinking) is a web-based tutoring program that uses animated agents to teach reading strategies to young adolescent (Grades 8-12) and college-aged students. The program is based on a live intervention called SERT (Self-Explanation Reading Training) that teaches metacognitive reading strategies in the context of self-explanation. SERT was motivated by empirical findings that students who self-explain text develop a deeper understanding of the concepts covered in text, combined with a large body of research showing the importance of reading strategies such as comprehension monitoring, making inferences, and elaboration. SERT was designed to improve self-explanation by teaching reading strategies, and in turn to facilitate the learning of reading strategies in the context of self-explanation. SERT has been found to successfully improve students' comprehension and course performance at both the college and high-school levels. iSTART was designed to deliver an automated version of SERT that could be more widely available and could adapt training to the needs of the student. This chapter will review the literature that motivated SERT and iSTART, describe the iSTART program, and describe research that has demonstrated the effectiveness of the training programs. This research has shown that self-explanation reading training is most beneficial for students with the least knowledge about the domain as well as the students who are less strategic or less-skilled readers. In other words, iSTART is most beneficial to at-risk readers. Current efforts for iSTART center on expanding the types of strategy training in order to increase its adaptability to students' needs.

iSTART: A Web-Based Tutor that Teaches

Self-Explanation and Metacognitive Reading Strategies

The goal of this chapter is to describe an automated tutoring system called iSTART (Interactive Strategy Trainer for Active Reading and Thinking) that is designed to provide reading strategy instruction to adolescent students. The chapter is organized into six sections that broadly cover the history and future development of iSTART. Section one provides the motivation for creating reading strategy interventions. Section two describes SERT (Self-Explanation Reading Training; McNamara, 2004b) and the empirical findings on the human-delivered strategy intervention that served as the impetus for creating iSTART. Section three describes the basic characteristics of iSTART including the overall structure of the program and the computational feedback system. Section four includes a description of our field studies on the effectives of the system in both college and high school settings, and an analysis of the relationship between self-explanation quality and comprehension performance. Section five discusses the role of metacognition within the system, and how metacognitive processes are encouraged implicitly through the structure of the program. Finally, section six discusses the limitations of the current system, and our future plans for improving iSTART and scaling up the program so it can be easily incorporated in large school settings.

1. A Need for Reading Strategy Interventions

The ability to comprehend from written text is one of the most complex, but critical, activities people perform everyday. From the time we wake up in the morning until the time we rest at night, we are bombarded with thousands of written messages including advertisements, instructions, newspapers, magazines, and textbooks. While successful comprehension can often appear effortless for skilled readers, the processes underlying the chain of activities necessary to

comprehend text are complicated. Successful comprehension entails a highly integrated set of activities that involves both lower level decoding abilities (e.g., Perfetti, 1985; Shankweiler et al., 1999) and higher-level integration abilities (Long, Oppy, & Seely, 1994; Magliano, Wiemer-Hastings, Millis, Muñoz, & McNamara, 2002; Oakhill & Yuill, 1996).

For example, in order to understand written text, individual letters must be decoded and combined to form words, sentences, and paragraphs. In addition, these combinations must adhere to a complex set of rules of grammar and syntax. Furthermore, the meaning must be derived from the integration of information contained in the text with the reader's prior knowledge (Kintsch, 1988, 1998). Potentially, at any stage of the reading comprehension process, comprehension can fail. While there have been a variety of interventions to improve comprehension at the lower levels (Fuchs & Fuchs, 2005; Kuhn, 2005), our focus has been on improving higher-level comprehension skills. That is, we have focused on students who can adequately decode, but who are poor comprehenders (Cain, 1996; Hoover & Gough, 1990; Stothard & Hulme, 1996; Cornoldi, DeBeni, & Pazzaglia, 1996).

The need for reading comprehension interventions is clear from several sources. First, recent research has indicated that students in the United States typically score lower on measures of reading comprehension as compared to students in other countries (Snow, 2002). Even more startling is the statistic that as many as 37% of fourth graders and 26% of eighth graders cannot read at the basic level (NAEP, 2003). In other words, these fourth and eighth graders do not understand what they read. Reading comprehension difficulties are even more pronounced for minorities: over half of minority students cannot read at the basic level (NAEP, 2003). Second, other research has indicated that students rarely use reading strategies to help them comprehend text (Pressley & Ghatala, 1990; Rothkopf, 1988; Garner, 1990; Pressley, Wood, Woloshyn,

Martin, King, & Menke, 1992), and when they do use strategies, students often implement rudimentary and ineffective methods such as repetition (Garner, 1990). Third, even when students read a text at the basic level, the level of comprehension is typically shallow and lacks the necessary depth for adequate understanding (Best, Rowe, Ozuru, & McNamara, 2005). Langer, 1989; Pressley et al., 1992). In short, there is a strong need for improving reading comprehension among students in the United States. Fortunately, interventions designed to improve comprehension have been successful (e.g., Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Chi, De Leeuw, Chiu, & LaVancher, 1994; Johnson-Glenberg, 2000; McNamara, 2004b; Meyer et al., 2002; Palincsar & Brown, 1984; Paris, Cross, & Lipson, 1984; Pressley et al., 1992).

2. SERT: Self-Explanation Reading Training

In response to the growing need for reading strategy training, McNamara and her colleagues (McNamara, 2004b; McNamara & Scott, 1999) developed a reading strategy training program called SERT (Self-Explanation Reading Training). SERT is a human-delivered reading strategy intervention that has drawn from nearly thirty years of research and theory on learning, memory, and reading comprehension. The broad scope of the training focuses on teaching students to become more active in constructing meaning through an integrative process of building a coherent model of the text in relation to the learner's prior knowledge. Particular focus has been directed at the active production of knowledge, as opposed to the passive reception of concepts within the text.

The positive effects of active production on learning have been supported from the literature on the learning and memory (Healy, Clawson, McNamara, et al., 1993). For example, research on the generation effect shows that information produced by oneself is better

remembered than information read more passively (e.g., McNamara & Healy, 2000). In general, research has shown that learning is improved when learners are forced to make more inferences and link new information with prior knowledge. SERT capitalizes on that notion in the sense that it encourages the reader to more actively approach text and use whatever knowledge available to make sense of it.

The backbone of SERT was largely motivated by research on self-explanation (Chi et al., 1994). The central idea is that students who explain the meaning of a text are more likely to make inferences, solve problems, construct coherent mental models, and develop a deep understanding of the information in the text (Chi et al., 1989, 1994). In short, self-explanation improves learning. However, not all readers successfully self-explain text. Thus, SERT builds on the benefits of self-explanation by providing a comprehensive and detailed training program that incorporates self-explanation, metacognitive skills, and reading comprehension strategies.

SERT is broken up into three core training sections: introduction, demonstration, and practice. In the introduction, students are introduced to the five core reading strategies and provided with examples of how these strategies could be applied while reading texts. The first strategy is comprehension monitoring which serves as an executive manager of the students' overall learning process. Students are taught to monitor whether or not they understand what they are reading. If students reach an impasse in their understanding, they are encouraged to use the other strategies to rectify the comprehension failure.

The second strategy is called paraphrasing and is used as a catalyst for self-explanation. Describing the text in one's own words serves two functions. First, it allows the reader to transform the material into a representation that is more familiar, and consequently more memorable. Second, the ability to paraphrase roughly translates into the most basic level of

comprehension because in order to paraphrase successfully, one must be able to process the basic structure and relations of the sentence to transform the verbatim text into more familiar words.

The third strategy, called elaboration, builds upon paraphrasing by encouraging readers to go beyond the text by using their prior knowledge, common sense, and logic to elaborate the text. Empirical findings indicate that prior knowledge plays an important role in learning (Shapiro, 2004; Thompson & Zamboanga, 2003). In particular, prior knowledge is critical in helping readers make the necessary inferences to fill gaps within the text (McNamara, Kintsch, Songer, & Kintsch, 1996). However, even when readers do not have any specific knowledge related to a text, SERT encourages them to elaborate by using general knowledge, logic, reasoning, or common sense to repair gaps in their understanding. In this manner, SERT encourages active, repair-directed processing as opposed to passivity when readers encounter an impasse.

The fourth strategy is prediction. While research indicates that predictions are relatively infrequent (Magliano, Trabasso, & Graesser, 1999), teaching students to predict what will occur next can be a useful exercise in metacognition. Forming a prediction requires reader to make plausible guesses about the future text content based on the current available evidence. Most importantly, checking to see whether a prediction is validated serves as a form of self-regulated learning.

The fifth strategy taught in SERT is called bridging. Bridging teaches the reader to link the concepts within the various parts of the text. Bridging is critical as many texts are not written in a manner that explicitly maps how the various concepts within the text are related (Beck, McKeown, & Gromoll, 1989). Bridging allows the reader to link concepts in both the proximal and distal sentences of the text to form a more global model of the content. In other words,

making bridges between the elements of the text fosters many of the inferences necessary to successfully comprehend the material.

These strategies can be mapped to levels of comprehension assumed by theories of text comprehension (Graesser, this volume; Kintsch, 1998). Strategies such as paraphrasing and bridging help the reader to better understand the basic meaning of the text, and thus strengthen the reader's textbase level of understanding. In turn, the last three strategies (elaboration, prediction, and bridging) strengthen the reader's situation model understanding. The principle point conveyed to the student is that they need to understand not only the concepts within the text, but also relationships between concepts in the text, and relationships between the text and what they already know. The inference generation strategies combined with the process of self-explanation help the reader to form a more coherent situation model. Making inferences is critical to successful comprehension because inferences help the reader to construct a more coherent mental representation of the text. Essentially, the goal is for the reader to seek coherence by using both the text and prior knowledge to create links between concepts.

Once the students have completed the introduction phase of the training, they proceed to the demonstration phase. During this phase of SERT, participants watch a video depicting a student reading and self-explaining a text about forest fires. Participants refer to an accompanying transcript while viewing the video. The video is paused at various points, and participants identify and discuss the strategies being used by the student in the video. During the final phase, practice, the participants work in pairs to practice self-explanation while reading a chapter from their science textbook. The participants take turns self-explaining, alternating after each paragraph. At the end of each paragraph, the partner who listens (and is not self-explaining) summarizes the paragraph.

Overall, SERT can be taught to small groups of students in about three hours of training. Empirical studies on the effectiveness of SERT have been very promising. Our results have shown that SERT is more effective than controls in improving college students' comprehension (Magliano, Todaro, Millis, Wiemer-Hastings, Kim, & McNamara, 2005, Exp.1; McNamara, 2004b) and science course performance (McNamara, submitted; for reviews see McNamara, 2004a; McNamara, Best, & Castellano, 2004; McNamara & Shapiro, in press). SERT has also improved comprehension for high-school students, in comparison to two other strategy interventions that emphasized knowledge activation and comprehension monitoring (O'Reilly, Best, & McNamara, 2004).

Of particular importance is the finding across studies that the effects of SERT are most evident for the students who show the lowest comprehension, that is, those with either low domain knowledge or low reading skills (McNamara, 2004b; McNamara, O'Reilly, Best, & Ozuru, submitted; O'Reilly, Best, & McNamara, 2004; O'Reilly, Sinclair, & McNamara, 2004a). This result indicates that the training is effective for students who need it the most: those who do not possess enough knowledge or those who do not automatically understand the relationships between concepts in the text. Protocol analyses have further revealed that SERT helps students compensate for their low knowledge by elaborating the text with their general knowledge and use logical and common sense to make the inferences to bridge knowledge gaps. In short, SERT has been successful in improving students' text comprehension, and the effects of the training seem to be more evident for those who need it most.

One question that this result raises concerns the relationship between incorrect explanation and comprehension. One might assume that low-knowledge and less skilled readers would be more likely to produce explanations with inaccurate information. In contrast, we have

not observed more inaccuracies in explanations for either low-knowledge or less skilled readers after they have been provided with strategy training (McNamara, 2004b; Ozuru et al., 2004). Moreover, McNamara (2004b) found a positive relationship between inaccurate elaborations and comprehension and no relationship between inaccurate bridging inferences and comprehension. Thus, elaboration helps to improve comprehension, regardless of whether the elaboration is accurate. Thus making inferences is critical to successful, coherent comprehension. Whether these inferences are initially accurate is not a driving factor, at least not in the context of self-explanation.

3. iSTART: The Program

While the effects SERT have been promising, there are several drawbacks to the human-delivered method of training. First, human training is costly because of the amount of time and resources required to train people how to teach SERT. Second, human-delivered feedback is inconsistent, and when given in group format, it cannot be easily optimized to the individual participant. Third, human training is not accessible to a large number of people at any time of the day. Given these constraints, McNamara and her colleagues (McNamara, Levinstein, & Boonthum, 2004) developed an automated version of SERT called iSTART (Interactive Strategy Trainer for Active Reading and Thinking). iSTART solves many of the problems associated with human-delivered training because the program can be optimized to the individual needs of the reader, and given that the system is web-based, the training can be scaled up to serve large scale needs.

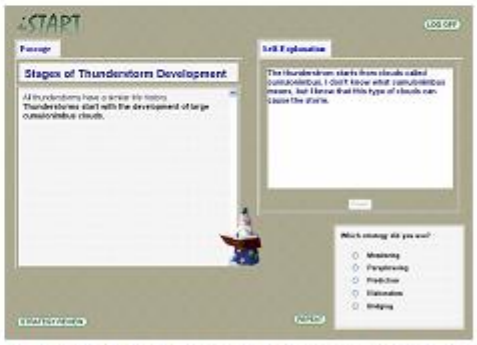
iSTART like SERT, is composed of three sections: introduction, demonstration, and practice. Each section provides progressively more interaction to the trainee with regard to reading strategy use while self-explaining text. As stated earlier, the purpose of the iSTART

trainer is to provide readers with strategies to comprehend texts at a deep level. iSTART provides the trainee with these abilities by teaching reading strategies in a scaffolded, structured manner. Each section of the program is hosted by animated pedagogical agents who provide the trainee with guidance and instruction using generated speech and gestures. Initially, the agents provide self-explanations while the trainee watches, but as the trainee progresses through the modules, they create self-explanations that are evaluated by the agents.

A. Screen shot of the three pedagogical agents (Dr. Julie, Sheila, and Mike) who deliver training during the Introduction Module of iSTART.

B. Screen shot of Merlin who gives a quiz during the Introduction Module of iSTART.

C. Screen shot of Merlin and Genie who deliver training during the Demonstration Module of iSTART.



D. Screen shot of Merlin who delivers training during the Practice Module of iSTART.

The introduction module introduces trainees to the reading strategies within a vicarious learning environment (McNamara, Levinstein, & Boonthum, 2004). The introduction is hosted by three pedagogical agents: Dr. Julie (the instructor agent), Mike, and Shelia (two learner agents). During the introduction, Dr. Julie introduces reading strategies and instructs Mike and Sheila on how to use the strategies. At this point, the learning environment is primarily vicarious: the

trainee observes proper use of the strategies from Mike and Shelia, but does not participate in their use. After the reading strategy is introduced by Dr. Julie and demonstrated by Mike and Shelia, the trainee must answer some review questions pertaining to the definition and to the application of the strategies used in example sentences.

The demonstration module provides an illustration of self-explanation through an interaction between two new pedagogical agents, Merlin (the teacher) and Genie (the learner) who use reading strategies to explain sentences in a science text. Merlin guides Genie in the use of self-explanation and reading strategies and Genie produces self-explanations, typically employing a combination of strategies. After Genie self-explains a sentence, Merlin assesses the quality of the self-explanation, thus providing an example of the feedback a trainee might receive when self-explaining in the subsequent, practice module. The trainee is questioned by Merlin each time that Genie produces an acceptable self-explanation. For example, the trainee might be asked what type of strategy was used by Genie, or where a particular strategy can be found within a self-explanation.

During the demonstration module, Merlin's questions adapt to the level of the trainee, providing different levels of support. Merlin has four levels of question style. The most supportive question style, level one, states and defines what strategy was used by Genie, rather than letting the trainee guess. The trainee is then asked to indicate in Genie's self-explanation where that strategy was used. Level two questions are identical to level one but the definition is removed. Level three questions ask the trainee what strategy was used by Genie and the trainee is presented with a menu to choose from. Two different strategies are usually required to be identified by the trainee in each self-explanation. With each strategy, follow-up questions are asked to focus the trainee on the details of the strategy and its use (e.g., "click on the part of the

text to which this explanation linked."). The trainee begins the demonstration module with questions at level three. Level four questions are the same as level three but do not contain follow-up questions. Merlin will progress to less structured questions if the trainee has a high success rate, whereas Merlin will provide structured, focused questions if the success rate is low.

During the practice module, the trainee practices the reading strategies they have learned. Merlin instructs the trainee to self-explain specific sentences in a text and the trainee's self-explanations are rated by the iSTART system so that Merlin can provide feedback. Merlin's feedback, based on a computational linguistic algorithms either asks for more information in the self-explanation or praises the self-explanation and allows the trainee to continue (McNamara, Boonthum, Levinstein, & Millis, in press; Millis, Kim, Todaro, Magliano, Wiemer-Hastings, & McNamara, 2004; Millis, Magliano, Wiemer-Hastings, Todaro, McNamara, in press). If allowed to proceed, the trainee may be asked what strategy was used or specifics about the strategy such as where it is located in the self-explanation.

Merlin's feedback is based on both the self-explanation and the target sentence, or the sentence being explained. In order to account for misspellings, words in the self-explanations are matched using a soundex (Knuth, 1998) transformation that drops vowels and maps similar characters to a single character. The appropriateness of the trainee's self-explanations is first assessed in three ways: length, similarity, and relevance. Self-explanations that have little in common with the target sentence and self-explanations that are simple restatements of the target sentence are unacceptable. The self-explanation must be sufficiently different from the target sentence but still be relevant to it. If the self-explanation is not long enough, different enough, or sufficiently relevant, more information is requested of the trainee. For example, if the self-

explanation is not long enough (in comparison to the length of the target sentence), Merlin asks for more information to be added to the self-explanation.

Relevance and similarity of the self-explanation and target sentence are established using content words from the target sentence and the other sentences in the text. The proportion of content words that overlap with the target sentence generally corresponds to the detection of a restatement or paraphrase of the sentence. The overlap in content words in the self-explanation with the content words from the other sentences in the text generally corresponds to a detection of the relevance of the self-explanation. Relevant self-explanations must contain a certain number of content words or associates. However, if the self-explanation contains too many content words from the target sentence in proportion to other content words, then the self-explanation is considered too similar. The feedback system in that case would ask for more information from the trainee.

If the self-explanation passes the initial screening, it is evaluated with respect to quality. The self-explanation quality is based on the same three factors as the initial assessment of the sentence but in addition uses LSA to judge a general conceptual overlap between the self-explanation and the text. The quality judgment guides the final feedback that Merlin provides to the trainee. For example, if the quality is low, Merlin might suggest making a bridging inference next time. Or, if the quality is high, Merlin would tell the trainee that the self-explanation was excellent.

4. Evidence that iSTART Works

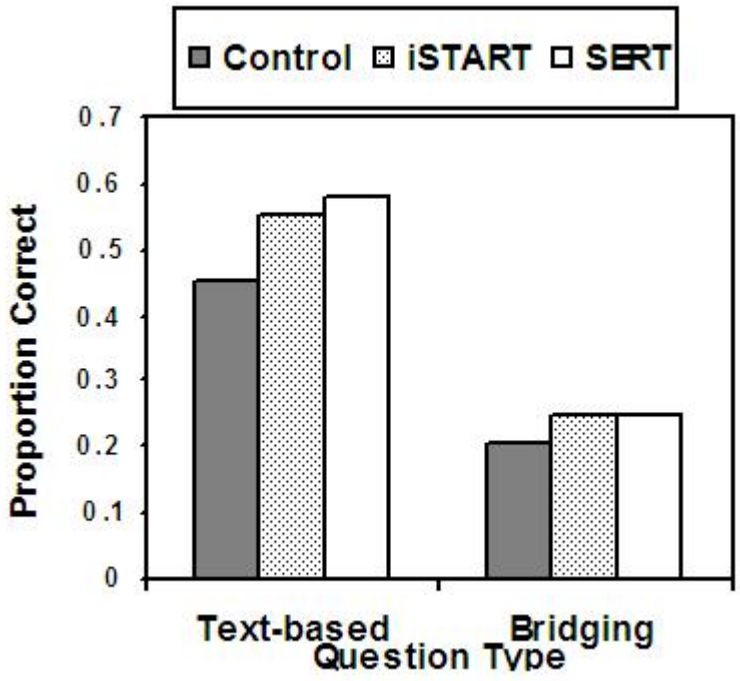
Empirical studies on the effectiveness of iSTART have been encouraging. Studies at both the college and high school levels have indicated that iSTART improves text comprehension and strategy use over control groups. There are two essential questions that the iSTART research

program has addressed: a) Is iSTART as effective as SERT?; and b) Who benefits from iSTART?

iSTART vs. SERT

One of the initial questions after developing our first version of iSTART was whether it matched SERT (the live, classroom training) in effectiveness. In separate studies, Magliano et al. (in press) showed that both SERT and iSTART were effective, but they did not directly compare the two training conditions. O'Reilly, Sinclair, and McNamara (2004b) conducted a study with college students enrolled in an introductory biology course to examine whether iSTART resulted in comprehension gains comparable to SERT. While automating the SERT intervention has several advantages, one potential problem is that automation may influence the effectiveness of SERT. In this study, the course lab sections were randomly assigned to one of three conditions: live SERT (trained by a human instructor), iSTART (trained by the computer program), and a control condition which had no training (and instead read a text and answered questions concerning it). After training, participants read a passage on cell mitosis (see McNamara, 2001). As shown in Figure 2, we confirmed that iSTART and SERT students answered more questions correctly than did students in the control condition. However, this main effect of condition was qualified by a significant interaction between condition and question type. There were two types of questions, text-based and bridging inference. Text-based questions could be answered based on individual sentences from the text, whereas bridging questions required multiple sentences and understanding the relationship between them. Text-based questions are intended to assess the readers' basic understanding of the text content, whereas bridging questions are intended to assess deeper level understanding that results from greater inferencing while reading. The interaction of condition and question type in this study indicated that the SERT and iSTART

participants outperformed control participants on text-based questions, but not bridging inference questions. The effect of training was marginal for the bridging questions. Thus, both SERT and iSTART improved students' comprehension, particularly at a basic, text-base level of understanding.



This result is somewhat disturbing because the goal of iSTART is to improve deep level understanding of the text. However, the results are congruent with three other studies that used the same cell mitosis text (McNamara, 2001; McNamara 2004b; O'Reilly & McNamara, in press). In all three studies, the effects of the manipulation intended to induce active processing produced effects on the text-based, but not the bridging inference questions. In the McNamara (2001) study and O'Reilly and McNamara (in press) study, the advantage of inducing inference generation for high-knowledge readers through less cohesive text only appeared on the text-based questions and in McNamara (2004b), the advantage of SERT only appeared on the text-based questions. One explanation of these results simply relates to the high difficulty of the text

and the topic of the text. That is, we might expect the level of a text's difficulty to influence whether improvement occurs at a lower or deeper level of processing: improvement at deeper levels of processing may be more likely for texts with moderate difficulty, and improvements at lower levels of processing may be more likely for texts with high difficulty.

This hypothesis is related to the notion of the zone of proximal development (Vygotsky, 1978). This is the idea that scaffolding helps a learner achieve a level of learning that is otherwise unachievable without scaffolding. Comprehension of the cell mitosis text without scaffolding is very poor - virtually a complete lack of understanding. With scaffolding, across these experiments, the readers were able to understand the basic ideas in the text. They were not, however, able to generate inferences and make links between ideas to allow them to perform well on the bridging inference questions.

So, we see that the idea that traces of deep processing will only appear on bridging inference questions may be too simplistic. In some cases, the benefits of deeper processing may only lead to a basic understanding of the information in the text. The important comparison is whether it is the case that without that deep or active processing, the reader would understand very little of the text.

Who benefits from iSTART?

There have been two intertwined questions regarding who would most benefit from iSTART. The first question was whether iSTART would benefit high-school students. Our research has shown that both SERT and iSTART benefit college students (McNamara, 2004b; O'Reilly et al., 2004b), and that SERT was beneficial to high-school students (O'Reilly, Best & McNamara, 2004; O'Reilly et al., 2004a). One of our main goals was for iSTART to be used in high-school classrooms, and thus a central aim has been to investigate its effectiveness with that

population. Much of the research we have conducted with high-school students is ongoing, in the sense that it has not yet been published. Thus far, 5 classroom studies in 35 high-school classrooms have been conducted to investigate the effectiveness of iSTART. This research has included almost 1000 students. However, this research is ongoing due to the complexity of scoring and analyzing the vast amount of data. Thus, this chapter only discusses our published research, leaving a description of our high-school classroom data for a future venue. Nonetheless, we can say that the preliminary analyses of our data are very promising, indicating that iSTART is quite effective with high-school students, and in some cases raises low comprehension students up to par with regular students.

A second set of questions has regarded whether the effects of iSTART depend on individual differences and how these effects manifest. Are there certain readers who don't need iSTART, or for whom it is too challenging? What is the role of prior domain knowledge? Do the benefits of iSTART depend on reading skill? There are two central goals to answering these types of questions. The first goal is to discover if there are certain students who do not need training, and the second goal is to discover if certain students need a different type of training.

One study investigated the effect of iSTART on adolescent students' comprehension and strategy use (McNamara et al., in press; O'Reilly, Sinclair, & McNamara, 2004a, 2004b). This study also examined whether the students' prior knowledge of reading strategies interacted with the benefits of strategy training (McNamara et al., in press). Half of the students were provided with iSTART while the students in the control condition were given a brief demonstration on how to self-explain text. All of the students then self-explained a text about heart disease and answered text-based and bridging-inference questions. We found that both iSTART training and prior knowledge of reading strategies significantly improved the quality of self-explanations, and

in turn, comprehension. In addition, we saw that the benefits of reading strategy instruction depended on prior reading strategy knowledge. For low-strategy knowledge participants, the effects of iSTART were more pronounced at the more literal text-based level. Conversely, for high strategy knowledge students, the effects of iSTART were evident on more difficult and integrative bridging inference questions. Protocol analyses indicated that iSTART improved the quality of the students' self-explanations, and in turn, the quality of the students' explanations was indicative of improved comprehension scores.

Thus, it appears that the majority of the students benefited from iSTART, but in different ways, and according to their zone of proximal development. Those with less knowledge of reading strategies needed to learn how to develop a coherent understanding of the basic information conveyed in each sentence of the text. In contrast, those with more prior knowledge of reading strategies were able to make more bridging inferences and elaborations, which translated to better performance on the bridging inference questions.

Magliano et al. (2005) found a similar pattern of results when they investigated whether and how the benefits of iSTART depended on the students' prior reading skill. In their study, college students read and self-explained two science texts before and after iSTART training. After reading the two texts, the students answered eight short-answer comprehension questions that corresponded to each text. Their reading skill was measured with the Nelson Denny Comprehension Test (Brown, Fishco, & Hanna, 1993). The experimenters found that skilled readers answered more bridging questions correctly after training, whereas less skilled readers improved on the text-based questions. Thus, more skilled readers learned strategies that allowed them to make more connections within the text, and this ability was most apparent on the bridging inference questions. In contrast, the less skilled readers learned the more basic level

strategies (such as paraphrasing) that allowed them to make sense of the individual sentences. Future research will reveal whether additional, extended training will help less skilled or less strategic readers to go beyond sentence-level understanding and develop the skills necessary for a coherent, global understanding of challenging text.

These results indicate that the students will make progress in their area of proximal development (e.g., Vygotsky, 1978). Readers need to first learn to form an adequate representation of the text-based information – essentially, the information presented in each individual sentence. Then, readers can learn how to understand the text at a deeper level by processing the relationships between the ideas conveyed across sentences and making links to world knowledge. iSTART can allow this progressive improvement by providing training at various levels of processing.

5. The Roles of Metacognition, Engagement, and Reflection in iSTART

One important aspect of iSTART is that the skills taught in iSTART are essentially metacognitive in nature. Metacognition refers to an individual's monitoring of cognitive processes and knowledge and use of cognitive processes for successful learning. When applied to reading, metacognition involves the reader's monitoring of whether the written material is successfully comprehended, coupled with active reading strategies that enhance and repair comprehension. iSTART provides metacognitive training first by explicitly teaching the students about and how to use metacognitive reading strategies. Additionally, iSTART adapts the constructivist modeling-scaffolding-fading paradigm to an automated curriculum by carefully increasing the engagement of the students and turning their attention to their own thought processes.

Metacognition and Engagement

The iSTART program initially provides the students with a safe, low-stakes environment in which they play the role of observer and gradually modifies that role until they become intellectually involved in self-explaining new texts. iSTART directs the student through three curricular phases: introduction, demonstration or modeling, and practice. There are four types of interaction in the iSTART curriculum, listed here from the least demanding to most demanding for the student:

a. *Navigational clicks.* The student clicks on a button to progress to the next step or to repeat an example.
b. *Well-defined choice clicks.* The student selects an answer from clearly defined items, for example, a set of radio buttons.
c. *Fuzzy choice clicks.* The student makes a choice but the choices are not clearly defined, for example, identifying where a certain strategy is used within an explanation.
d. *Production of text in response to a prompt.* The student is asked to type an explanation of a given sentence.

The ultimate aim of iSTART goes beyond this last item: the production of unprompted explanation directed by cognitive monitoring. As students progress through this curriculum, the changes in engagement are evident in the changes in the type of interaction demanded by the program: the proportion of navigational and well-defined choice clicks declines, and fuzzy choices and the production of text increases. This progress is scaffolded by a simulated social environment consisting of animated characters that provide instruction, examples, coaching and assistance. The sections below describe how metacognition and engagement emerge within the three modules of iSTART.

Introduction. The introduction is presented by three animated characters, as described earlier. Dr. Julie presents each reading strategy with definitions and examples to the animated students (Mike and Sheila) who ask questions and try out the strategies under her coaching. The actual student who is being tutored merely observes this interchange and participates only by making limited choices: clicking on a button to continue after having studied an example on the blackboard or clicking on a button to repeat an example or to see a second example. The student's interaction at this point is minimal, consisting of a few navigational clicks in each of the eight modules.

The level of engagement is stepped up with brief quizzes that follow the presentation of each strategy. The quiz is actually a pedagogical tool for providing additional instruction when needed as well as a means of assessing the learner. Each quiz consists of four multiple-choice questions that tap the student's understanding of the definition of the strategy and the ability to identify good examples of the strategy. While the quizzes put the student "on the spot" much more so than the animated expository modules, they also scaffold the student by providing prompts and hints when an incorrect answer is chosen. In the first instance of an incorrect answer choice, the student is asked to try again. With a second error, the student is reminded of the definition of the strategy. If the student makes any errors, the final, correct choice is followed by an explanation of the correct answer.

Demonstration. While the introduction alternates several minutes of observation with several minutes of testing, the demonstration module shortens the period of this alternation and makes more difficult demands on the student. Merlin, the coach seen earlier during the quizzes, supervises a new character, Genie, a surrogate learner who reads and self-explains a passage sentence by sentence. Genie's explanation remains available to the student in a text box on the

screen. While Genie appears to be the one “on the spot” to produce a self-explanation acceptable to Merlin, the student, who observes their interaction, is also “on the spot” since she or he is questioned about the strategies used in each self-explanation. Although they are questioned more often during demonstration than the introduction, students are still in a protective environment in the demonstration section because Merlin gives them several chances to answer and because the trainer adapts the mode of questioning to the students’ success (as described earlier). At a lower level of questioning, Merlin presents the students with a list of strategies and asks them to click on any strategy used in the self-explanation. More challenging follow-up questions require the student to identify where a certain strategy appeared within the self-explanation, or what text is related to Genie’s self-explanation (i.e., to identify the source of a bridging inference). These are interactions of the fuzzy choice variety. Answering these questions demands more difficult thought processes than answering the questions in the introduction. There the students had to decide among well-defined choices, such as which of several explanations counted as bridging. Now Genie’s explanation must be mentally separated into parts and the parts matched up with one or another of the strategies on the list. When students have difficulty with this mode of questioning, the trainer adapts by simplifying the question.

Overall, the demonstration module requires more interaction and higher-level thought processes from the students than required during the introduction. No longer is the interaction primarily among the animated characters while the trainee mostly navigates through the material. Instead, the trainees alternately observe and participate by analyzing the competencies they will be expected to exhibit in the next phase of training. In the introduction, all clicks are made on constrained choices, while in the demonstration section more than half are fuzzy choices, made

on the text of an explanation or the passage being explained, a process that requires careful reading or parsing.

Practice. In the practice module, the student takes on the role that Genie played in the demonstration module and types explanations of the sentences in a new text under Merlin's coaching. Here, the student is much more "on the spot" and is no longer observing others, but fully participating by creating explanations. Merlin coaches by encouraging the student to develop an explanation of at least minimal acceptability and then provides more or less enthusiastic feedback depending on the quality of the explanation. Merlin also asks the student to identify the strategies used in the explanations just as he asked about Genie's explanations during the demonstration module. The students' engagement with the program in the practice module goes beyond what it was in demonstration, a combination of well-defined and fuzzy choices because they produce text at Merlin's prompts and analyze their own explanations rather than Genie's. The learner no longer simply clicks to interact with the program but focuses on explaining the sentences as they are presented.

Modeling-Scaffolding-Fading

Modeling and Scaffolding. iSTART makes sophisticated use of the modeling-scaffolding-fading paradigm. The competency of using the strategies to self-explain a sentence is modeled in the first two parts of the curriculum. Scaffolding is provided throughout but fades as the student becomes successful. In the introduction, the use of strategies is modeled by Dr. Julie who provides many examples of good explanations and by the student characters, Mike and Sheila, who are coached through the process as well. This modeling is reinforced because the explanations are heard, seen in bubbles as the words are spoken, and preserved on a blackboard for later discussion.

In the demonstration module, Genie, although cast as a student, is actually an expert self-explainer most of the time (early on Genie produces an inadequate explanation so that the students can observe the sort of coaching they will receive when Merlin complains about their explanations in the practice module). His explanations typically use several strategies and are generally longer than the explanations actually provided by students using iSTART. As in the introduction, the explanations are presented verbally, as text in the balloons as they are spoken, and are preserved in a textbox on the screen. Modeling can only be effective if the student attends to it. In this module, the student is strongly encouraged to attend by being questioned in detail about Genie's explanations. Even if the student fails to pay attention while Genie is speaking, the explanation is reproduced on the screen while the student is being questioned.

The trainer provides the students with a great deal of scaffolding as they make their observations and analyses. In the introduction module, the students are able to repeat the examples that model self-explanation at the click of a button and they are coached in the quizzes. In the demonstration module, Merlin matches his style of questioning to the success of the student and a color coded analysis of each self-explanation is provided for study before proceeding to the next sentence. The practice module continues the scaffolding. Merlin identifies explanations that are irrelevant, too short, or too similar to the original sentence and encourages the student to modify and expand them. When a student seems to be having too much trouble, the Genie character appears, coming to the rescue and offering more detailed assistance. Since students are regularly asked which of the strategies they have used and are shown a list to choose from, they are constantly reminded of all the available strategies. When a student persists in identifying only comprehension monitoring and paraphrasing, Merlin encourages him or her to

use other strategies as well. Finally, the student is motivated to construct better self-explanations by Merlin's feedback which can range from ho-hum to enthusiastic.

Fading. It is an essential part of the paradigm that students learn to proceed without scaffolding so that they can employ their competencies autonomously. iSTART brings fading into play after the introduction module by reducing scaffolding in line with student success. In the demonstration module, this takes two forms. As a student becomes more successful in identifying the strategies used, the mode of questioning becomes less supportive. In addition, with continued success, fewer follow-up questions are posed, allowing the student to move more quickly through the curriculum. In the practice module, a similar tactic is used: successful students are asked fewer follow-up questions and queried less about the strategies they used. Merlin may just compliment their explanation and move on to the next sentence. The initial coached sessions of practice may be followed in subsequent weeks with refresher practices which are almost entirely uncoached unless the student runs into difficulty.

Reflection

The competencies taught by iSTART are unusual in that no specific subject matter mastery is involved. Indeed, although the trainer seems to place a high value on identifying strategies used in explanations, that skill is promoted only as part of a pedagogy that ultimately engages the students in the practice of effective self-explanations. Strategy identification is a mechanism by which the students learn to think about and direct their own thinking as they read, that is, as they learn to read reflectively. iSTART induces this change by building a bridge between the concepts of strategic reading and the performance of strategic reading. In the introduction, the concepts are introduced and then modeled individually by Dr. Julie. Mike and Sheila then model learning to use self-explanation. The students observe all of this, encountering

self-explanations in various forms. They also identify types of self-explanations during the quizzes. This identification practice is put to work in the demonstration module, where the students observe Genie self-explaining, again encountering the explanations as both performance and text, and practice the identification skills on Genie's explanations. Finally in the practice module, the students produce their own self-explanations. Here the fact that the explanations are typed is crucial, there is virtually no difference between applying strategy identification to Genie's explanations and their own. By varying the students' perspective from that of observer, to critic, to producer of self-explanations, the students learn autonomous, reflective self-explanation.

6. The Future of iSTART

Our current efforts are being directed on expanding the iSTART program so that it is more adaptive to student needs and can be more easily used in a classroom. The results discussed earlier in the chapter showed that for both adolescents (McNamara et al., submitted) and college students (Magliano et al., 2005), the benefits of iSTART for less strategic or less-skilled readers occur only at the textbase level of comprehension. These results suggest that less-skilled readers may benefit from more extensive training than currently provided by iSTART. More extensive training could potentially allow less-skilled readers the necessary time and practice to be able to successfully use the more complex strategies such as bridging inferences and elaborations. Some of our current efforts are directed toward expanding iSTART so that it provides more extensive training and with a greater range of strategies. Developing procedures to tailor feedback to meet the needs of high-risk, struggling readers should make iSTART more effective for a wider range of students. For example, assessing prior knowledge of reading strategies will allow us to better tailor training. In future versions of iSTART, less-skilled and low strategy knowledge students

will receive more training overall. First, they will receive more training in lower level strategies, and more positive feedback for strategies such as paraphrasing. This will then provide them with a stronger foothold to help them to move on to deeper level strategies. In contrast, we will continue to push more skilled students to go beyond the text by using strategies such as elaboration to create coherence.

We are also increasing the number and variety of texts that can be self-explained. In this way, the students will have the opportunity to a greater amount of training and to learn the strategies with a wider variety of text genres. A greater amount of training will allow less skilled students to develop higher level skills necessary to build a deep understanding of difficult texts. The use of a wider variety of text genres will help the student to learn when and how to use self-explanation and other reading strategies in multiple contexts.

Finally, we are developing a teacher interface to help manage what the students read and to monitor their progress. The interface will allow teachers to more easily make use of iSTART in their classrooms according to their own needs. Incorporating a computerized trainer into a classroom is not as simple as just giving it to the teacher and expecting that it be used consistently or successfully.

There are many teacher needs that must be met to reach our goals. First, the teachers must understand the need for reading strategy training and be receptive to intelligent tutoring systems. Hence, we are developing an automated program for teachers to provide information about the importance of reading strategies and information about iSTART, particularly how it helps students to read and understand difficult material. Second, the program must be easy for the teacher to use and answer the questions that the teacher has concerning the program and the students' progress. Thus, a program is being developed to facilitate teachers' use of iSTART in

the classroom. Third, teachers are pressed to cover an increasing amount of content, causing many to drop the deep-learning activities that take 'extra time.' Thus, the learning material covered in iSTART must be relevant to the course demands. Currently, iSTART tutors students using a limited number of texts, covering content that may or may not be relevant to the particular course. Therefore, we are increasing the number of course topics that can be covered during demonstration and practice and increase the difficulty range of practice texts. Teachers will be able to assign texts or topics for self-explanation training that are being covered in class – reducing time taken away from course material and thereby improving students' understanding of the course topic.

Like many of the other reading strategy interventions presented in this volume, our motivation for the iSTART project is to address what we view as a critical need in our educational system – to provide a large number of students with reading strategy training based on empirically-supported and theoretically grounded reading strategy research. Our research has clearly documented the success of SERT and iSTART in terms of improving self-explanation abilities, comprehension success, and course grades. Hence, we are confident that iSTART has the potential to have a marked impact on students' reading abilities across the United States.

References

Beck, I., McKeown, M., & Gromoll, E. (1989). Learning from social studies texts. *Cognition and Instruction, 6*, 99-158.

Best, R M., Rowe, M. P., Ozuru, Y., & McNamara, D. S. (2005). Deep-level comprehension of science texts: The role of the reader and the text. *Topics in Language Disorders, 25*, 65-83.

Brown, J., Fishco, V., & Hanna, G. (1993). *Manual for Scoring and Interpretation*, Forms G&H. Chicago, Illinois: Riverside Press.

Cain, K. (1996). Story knowledge and comprehension skill. In Cornoldi, C. & Oakhill, J. (Eds.), *Reading comprehension difficulties* (pp. 167-192). New Jersey: Lawrence Erlbaum Associates, Publishers.

Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science, 13*, 145-182.

Chi, M. T. H., De Leeuw, N., Chiu, M., & LaVancher, C. (1994). Eliciting self explanations improves understanding. *Cognitive Science, 18*, 439-477.

Cornoldi, C., DeBeni, R., & Pazzaglia, F. (1996). Profiles of reading comprehension difficulties: An analysis of single cases. In C. Cornoldi and J. Oakhill (Eds.), Reading comprehension difficulties, New Jersey: Lawrence Erlbaum Associates, Publishers.

Fuchs, D., & Fuchs, L. (2005). Peer-Assisted Learning Strategies: Promoting Word Recognition, Fluency, and Reading Comprehension in Young Children. *Journal-of-Special-Education, 39*, 34-44

Garner, R. (1990). When children and adults do not use learning strategies: Toward a theory of settings. *Review of Educational Psychology, 60*, 517-529.

Healy, A. F., Clawson, D. M., McNamara, D. S., Marmie, W. R., Schneider, V. I., Rickard, T. C., Crutcher, R. J., King, C., Ericsson, K. A., & Bourne, L. E., Jr. (1993). The longterm retention of knowledge and skills. In D. Medin (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 30, pp. 135-164). New York: Academic Press.

Hoover, W., & Gough, P. (1990). The simple view of reading. *Reading and Writing, 2*, 127-160.

Graesser, A.C. (this volume). An introduction to strategic reading comprehension.

Johnson-Glenberg, M. (2000). Training reading comprehension in adequate decoders/poor comprehenders: Verbal versus visual strategies. *Journal of Educational Psychology, 92*, 772-782.

Kintsch, W. (1988). The use of knowledge in discourse processing: A construction integration model. *Psychological Review, 95*, 163-182.

Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. Cambridge, MA: Cambridge University Press.

Knuth, D. E. (1998). *The art of computer programming, Vol. 3: Sorting and searching, 3rd ed.* Reading, MA: Addison-Wesley.

Kuhn, M. (2005). A comparative study of small group fluency instruction. *Reading-Psychology, 26*, 127-146.

Langer, E. J. (1989). *Mindfulness*. Reading, MA: Addison-Wesley.

Long, D. L., Oppy, B. J., & Seely, M. R. (1994). Individual differences in the time course of inferential processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 1456-1470.

Magliano, J.P., Todaro, S. Millis, K.K., Wiemer-Hastings, K., Kim, H.J., & McNamara, D.S., (2005). Changes in reading strategies as a function of reading training: A comparison of live and computerized training. *Journal of Educational Computing Research, 32,* 185-208.

Magliano, J. P., Trabasso, T., & Graesser, A. C. (1999). Strategic Processing During Comprehension. *Journal of Educational Psychology, 91(4),* 615-629.

Magliano, J. P., Wiemer-Hastings, K., Millis, K. K., Muñoz, B. D., & McNamara, D. S. (2002). Using latent semantic analysis to assess reader strategies. *Behavior Research Methods, Instruments, and Computers, 34*, 181-188.

McNamara, D. S. (2001). Reading both high coherence and low coherence texts: Effects of text sequence and prior knowledge. *Canadian Journal of Experimental Psychology, 55*, 51-62.

McNamara, D. S. (2004a). Aprendiendo a través de los textos: efectos de la estructura del texto y las estrategias de los lectores. *Signos, 37*, 123-159.

McNamara, D. S. (2004b). SERT: Self-explanation reading training. *Discourse Processes, 38,* 1-30.

McNamara, D.S. (submitted). SERT Improves Low-Knowledge Students' Science Course Performance. Submitted to Discourse Processes.

McNamara, D. S., Best, R., & Castellano, C. (2004). *Learning from Text: Facilitating and enhancing comprehension.* www.speechpathology.com.

McNamara, D. S., Boonthum, C., Levinstein, I. B., & Millis, K. (in press). Using LSA and word-based measures to assess self-explanations in iSTART. In T. Landauer, D.S., McNamara, S. Dennis, & W. Kintsch (Eds.), *LSA: A Road to Meaning.* Mahwah, NJ: Erlbaum.

McNamara, D. S., & Healy, A. F. (2000). A procedural explanation of the generation effect for simple and difficult multiplication problems and answers. Journal of Memory and Language, 43, 652-679.

McNamara, D. S., Kintsch, E., Songer, N., & Kintsch, W. (1996). Are good texts always better? Interactions of text coherence, background knowledge, and levels of understanding in learning from text. *Cognition and Instruction, 14*, 1-43.

McNamara, D. S., Levinstein, I. B., & Boonthum, C. (2004). iSTART: Interactive strategy trainer for active reading and thinking. *Behavioral Research Methods, Instruments, and Computers, 36*, 222-233.

McNamara, D. S., O'Reilly, T., Best, R., & Ozuru, Y. (2006). Improving adolescent students' reading comprehension with iSTART. *Journal of Educational Computing Research, 34*, 147-171.

McNamara, D. S., & Scott, J. L. (1999). Training reading strategies. *Proceedings of the Twenty first Annual Meeting of the Cognitive Science Society*. Hillsdale, NJ: Erlbaum.

McNamara, D. S., & Shapiro, A. M. (in press). Multimedia and hypermedia Solutions for promoting metacognitive engagement, coherence, and learning. *Journal of Educational Computing Research*

Meyer, B. J. F., Middlemiss, W., Theodorou, E., S., Brezinski, K. L., McDougall, J., & Bartlett, B. J. (2002). Older adults tutoring fifth-grade children in the structure strategy via the Internet. *Journal of Educational Psychology, 94*, 486-519.

Millis, K.K., Kim, H.J., Todaro, S., Magliano, J., Wiemer-Hastings, K., & McNamara, D. (2004). Identifying reading strategies using latent semantic analysis: Comparing semantic benchmarks. *Behavior Research Methods, Instruments, & Computers, 36*, 213–221.

Millis, K., Magliano, J., Wiemer-Hastings, K., Todaro, S., McNamara, D. S. (in press). Assessing comprehension with Latent Semantic Analysis. In T. Landauer, D.S., McNamara, S. Dennis, & W. Kintsch (Eds.), *LSA: A Road to Meaning.* Mahwah, NJ: Erlbaum.

National Assessment for Educational Progress. (2003). The Nation's Report Card: Reading Highlights, NCES Number: 2004452. Release Date: November 13, 2003.

Oakhill, J., & Yuill, N. (1996). Higher order factors in comprehension disability: Processes and remediation. In C. Cornaldi & J. Oakhill (Eds.), *Reading comprehension difficulties: Processes and Intervention*. Mahwah, NJ: Erlbaum.

O'Reilly, T., Best, R., & McNamara, D. S. (2004). Self-Explanation Reading Training: Effects for Low-Knowledge Readers. In K. Forbus, D. Gentner, T. Regier (Eds.), *Proceedings of the 26th Annual Meeting of the Cognitive Science Society* (pp. 1053-1058). Mahwah, NJ: Erlbaum.

O'Reilly, T., & McNamara, D. S. (in press). Good texts can be better for skilled comprehenders. Discourse Processes.

O'Reilly, T.P., Sinclair, G.P., & McNamara, D.S. (2004a). iSTART: A web-based reading strategy intervention that improves students' science comprehension. In Kinshuk, D. G. Sampson, & P. Isaías (Eds.), Proceedings of the IADIS International Conference Cognition and Exploratory Learning in Digital Age: CELDA 2004 (pp. 173-180). Lisbon, Portugal: IADIS Press.

O'Reilly, T. P., Sinclair, G. P., & McNamara, D. S. (2004b). Reading strategy training: Automated versus live. In K. Forbus, D. Gentner, T. Regier (Eds.), Proceedings of the 26th Annual Meeting of the Cognitive Science Society (pp. 1059-1064). Mahwah, NJ: Erlbaum.

Ozuru, Y., Best, R., & McNamara, D. S. (2004). Contribution of reading skill to learning from expository texts. In K. Forbus, D. Gentner, T. Regier (Eds.), *Proceedings of the 26th Annual Meeting of the Cognitive Science Society* (pp. 1071-1076). Mahwah, NJ: Erlbaum.

Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and monitoring activities. Cognition and Instruction, 2, 117-175.

Paris, S., Cross, D., & Lipson, M. (1984). Informed strategies for learning: A program to improve children's reading awareness and comprehension. Journal of Educational Psychology, 76, 1239-1252.

Perfetti, C. (1985). *Reading ability*. New York: Oxford University Press.

Pressley, M, & Ghatala, E. (1990). Self-regulated learning: Monitoring learning from text. *Educational Psychologist, 25,* 19-33.

Pressley, M., Wood, W. W., Woloshyn, V. E., Martin, V., King, A., & Menke, D. (1992). Encouraging mindful use of prior knowledge: Attempting to construct explanatory answers facilitates learning. *Educational Psychologist, 27*, 91-100.

Rothkopf, E. Z. (1988). Perspectives on study skills training in a realistic instructional economy. In C.E. Weinstein, E.T. Goetz, & P.A. Alexander (Eds.), *Learning and study strategies: Issues in assessment, instruction, and evaluation*. San Diego, CA: Academic Press.

Shankweiler, D., Lundquist, E., Katz, L., Stuebing, K., Fletcher, J., Brady, S., Fowler, A., Dreyer, L., Marchione, K., Shaywitz, S., & Shaywitz, B. (1999). Comprehension and decoding: Patterns of association in children with reading difficulties. *Scientific Studies of Reading, 3*, 69-94.

Shapiro, A. M. (2004). How including prior knowledge as a subject variable can change outcomes of learning research. *American Educational Research Journal, 41*, 159-189.

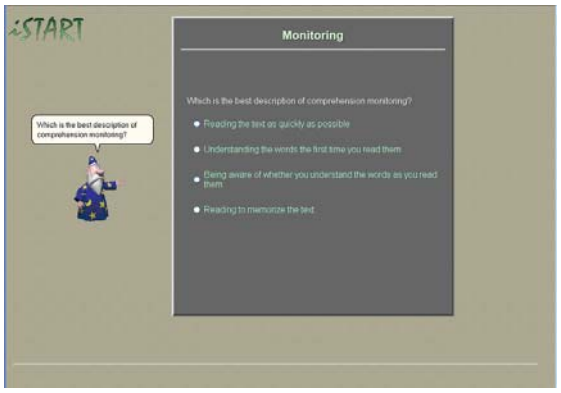
Snow, C. (2002). *Reading for understanding: Toward an R&D program in reading comprehension*. Santa Monica, CA: RAND.

Stothard, S. E., & Hulme, C. (1996). A comparison of reading comprehension and decoding difficulties in children. In C. Cornoldi and J. Oakhill (Eds.), *Reading comprehension difficulties*, (pp. 93-112). New Jersey: Lawrence Erlbaum Associates, Publishers.

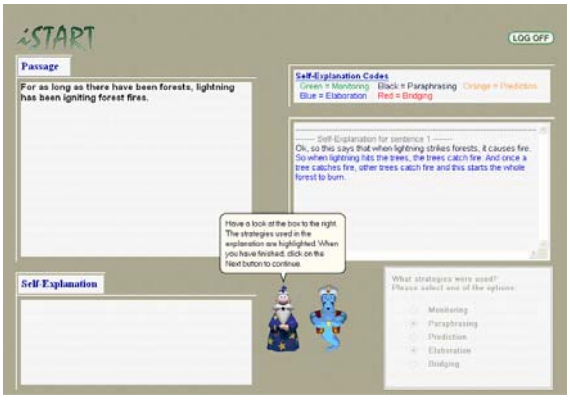
Thompson, R. A., & Zamboanga, B. L. (2003). Prior knowledge and its relevance to student achievement in Introduction to Psychology. *Teaching of Psychology, 30,* 96-101.

Vygotsky, L. (1978). *Mind in society*. Cambridge, MA: MIT Press.

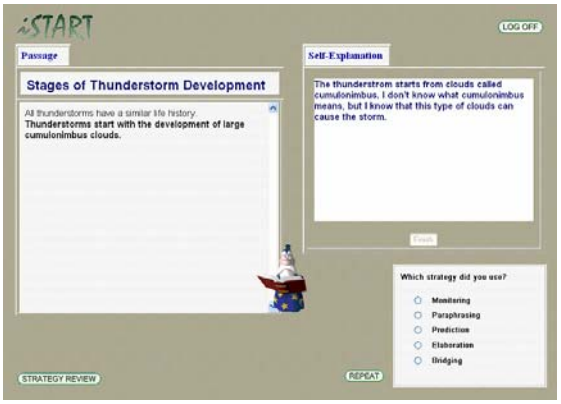
A. Screen shot of the three pedagogical agents (Dr. Julie, Sheila, and Mike) who deliver training during the Introduction Module of iSTART.



B. Screen shot of Merlin who gives a quiz during the Introduction Module of iSTART.



C. Screen shot of Merlin and Genie who deliver training during the Demonstration Module of iSTART.



D. Screen shot of Merlin who delivers training during the Practice Module of iSTART.

Figure 1. iSTART sample screen shots.

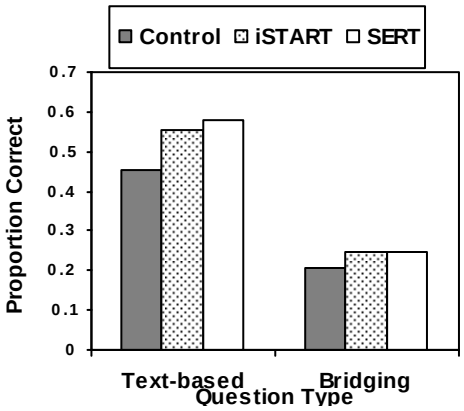


Figure 2. Comprehension of the cell mitosis text as a function of training condition and question type.