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Design and Pilot of a Web-Based Intelligent Tutoring System to Improve Reading Comprehension in Middle School Students

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Children and adults of all ages have improved their reading comprehension when trained to use the Structure Strategy to read, understand, and recall information from expository text. Training on the structure strategy has been conducted in small groups or using one-on-one tutoring and some web-pages with email tutoring, all showing significant improvements in comprehension. We are creating a web-based intelligent tutoring system to present the strategy to 5th-7th grade students. The advantages of web-based tutors are: consistent tutoring technique, modeling of good practice, scaffolding, immediate feedback, and motivation. This paper presents the foundations of our project Intelligent Tutoring for the Structure Strategy (ITSS), supporting research for the design, and preliminary findings from pilot tests.

Keywords: Intelligent Tutoring, Reading Comprehension, Structure Strategy

INTRODUCTION

Reading comprehension is a fundamental unit of all human activities. Students in elementary and middle schools need to read and comprehend information to succeed in all their future activities. The National Center for Education Statistics annual report on reading showed that 37% of fourth graders and 26% of eighth graders performed below basic levels of reading (NCES, 2003). The Structure Strategy (SS) is one approach to

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improving students' reading comprehension (Meyer et al., 2002). Extensive research on the SS has shown significant improvements in reading comprehension for readers of all ages (Meyer et al., 2002). The SS teaches students that expository texts have six basic text structures: Comparison, Problem and Solution, Cause and Effect, Description, Sequence, and Listing. These structures have unique signaling words that should cue the student to organize the reading and recall using this knowledge. Extensive research has been conducted with human tutors training students on using the Structure Strategy and the results have been overwhelmingly positive (Armbruster, Anderson, & Ostertag, 1987; Bartlett, 1978; Carrell, 1985; Cook & Mayer, 1988; Englert & Hiebert, 1984; Gordon, 1990; Meyer, 1999; Meyer & Poon, 2001; Meyer, Young, & Bartlett, 1989; Paris, Cross, & Lipson, 1984; Polley, 1994). The methods employed in these studies require trained human tutors and many tutors to expand the training to a larger audience in schools.

The solution to this problem of needing a large number of trained tutors is the use of "intelligent" computer tutors to train students on using the Structure Strategy. The intelligent tutors can provide good modeling, motivation, feedback, consistency, and access. Based on extensive review of the available technologies and research we have chosen web-based intelligent tutoring systems with software agents as our approach to provide this solution. Our US Department of Education – Institute of Education Sciences funded project is designed to create an Intelligent Tutoring system for the Structure Strategy (ITSS) and research the effectiveness of the ITSS in 5th-7th grade students.

This paper reports on our goals, approach to designing the ITSS, review of relevant research, and pilot test.

DESIGNING THE ITSS

The goals of the ITSS are to help children learn to use the Structure Strategy to read and comprehend expository text. Our design goals for the ITSS are to build a motivating, easily accessible, and interactive environment (Meyer & Wijekumar, in press). Motivational components are based on the age of the learners, current topics of interest, school curriculum, interviews with students, experiences of other researchers working with children, teacher comments, and a reward system. The use of a web-browser with a Flash plug-in makes the ITSS easily accessible. Finally, the system is interactive. ITSS enables us to model Structure Strategy use, collect students' responses to questions, assess students' responses, and provide immediate and consistent feedback on their performance.

These design elements were synthesized from reviewing the current research and our experiences. The review of research described next included the Structure Strategy, multimedia learning, and intelligent tutoring environments.

STRUCTURE STRATEGY RESEARCH

Research on the Structure Strategy showed that the method helps readers to focus on the text organization, helping them organize their reading accordingly, and showing significant improvement in recall of expository text (e.g., Meyer, 1999). Meyer, Young, & Bartlett (1989) found that the strategy helped readers remember more ideas and more important ideas, as well as remembering the ideas longer.

Some students fail to succeed in tasks such as identifying main ideas from expository text and giving cohesive and complete accounts of what they read because of how they read, rather than because they do not read. Meyer, Brandt, and Bluth (1980) showed that good readers in the ninth grade (as measured by standardized reading achievement tests and corroborated by teacher appraisals) could use the structure strategy, while most poor

readers could not.

In a recent pilot study conducted by Dr. Meyer, we randomly sampled 33% of the fifth-grade students from large, suburban middle school noted for high academic achievement (Reading Comprehension subtest of the Comprehensive Testing Program [CTP] [Educational Records Bureau, 1992] = 72 percentile). We found that only 30% of the students organized recall of information remembered from a short newspaper article with a problem part and a solution part, giving evidence for using the structure strategy. Most of the students organized recall as a list of unrelated facts, rather than ideas interrelated with a problem/solution structure. Clearly, specific difficulty in using the structure of text in reading for meaning is empirically linked to low levels of academic achievement in reading.

After the primary grades, children increasingly are expected to learn from expository text in science, history, social studies, and current events (Gersten, Fuchs, Williams, & Baker, 2001; Wilson & Rupley, 1997). Reading comprehension from such text is critical for academic success in school (National Educational Goals Panel, 1999). Understanding and remembering information from expository text is important throughout the life span to further develop intellectual abilities (Ackerman, 1998) and maintain functional independence (e.g., health maintenance and financial management, Meyer, Talbot, Poon, & Johnson, 2001). As society becomes more technologically advanced, understanding expository text becomes increasingly important (Alexander & Jetton, 2000; Gersten et al., 2001; Lapp, Flood, & Ranck-Buhr, 1995).

Instruction about text structures has yielded positive effects for understanding and remembering information from text with children, young adults, and older adults (Armbruster et al., 1987; Bartlett, 1978; Carrell, 1985; Cook & Mayer, 1988; Englert & Hiebert, 1984; Gordon, 1990; Meyer, 1999; Meyer et al., 2002; Meyer & Poon, 2001; Meyer et al., 1989; Paris et al., 1984; Polley, 1994; Raphael & Kirschner, 1985; Richgels, McGee, Lomax, & Sheard, 1987; Samuel et al., 1988; Slater, Graves, & Piche, 1985; Taylor & Beach, 1984; Weisberg & Balajthy, 1989).

MULTIMEDIA & MOTIVATION RESEARCH

Multimedia research is an integral part of any web-based intelligent tutoring system because the intelligent tutoring systems use the multimedia capabilities to present the content. Current research on multimedia learning effects suggest that students' perceptual channels should not be overloaded with too much text or unrelated graphics (Mayer & Moreno, 2003; Mayer, 2001). Students in multimedia environments attend to listening and text better than multiple text windows that compete for their attention (Mayer, 2001).

Research on motivation shows that students' engagement is enhanced with the use of more interesting (both situational and personal interest; e.g., Alexander & Jetton, 2000; Hidi, 1990) authentic text selections, student choices of text passages, immediate and encouraging feedback, content goals embedded in the lessons, and ways for students to track individual goal setting related to mastering the strategy (Wijekumar, Meyer, Ferguson, & Wagoner, 2006).

INTELLIGENT TUTORING RESEARCH

Intelligent Tutoring (IT) research shows that they are very effective in learning environments. IT is a field of research with great promise in reaching new audiences, maintaining consistency, motivating, providing immediate feedback, and delivering effective tutoring (Anderson, Corbett, Koedinger, & Pelletier, 1995). The intelligent

tutors range from simple text based interface tutors using key-word searches to find the correct responses to human-like talking heads that use Latent Semantic Analysis (LSA) or Bayesian reasoning to interact with the users. Current applications of these agents include physics tutoring (Graesser et al., 1999), promoting reflective thinking (Baylor, 2001a), teaching biology (Moreno, 2001), and psychological counseling for families (Johnson, 2001). Research has shown that these agent tutors are believable (Moreno, 2001), improve performance by at least 1 standard deviation (SD) compared to human tutors 2 SD (Cohen, Kulik, & Kulik, 1982), and are useful to convey feedback through their facial mannerisms (Graesser, Person, & Magliano, 1995; Link et al., 2001; Person et al., 2001).

Baylor (2001b) has also shown that students interacting with software agents attend to the advice, consider the advice and agent useful, and enjoy working with agents. A tutoring system for reading showed significant improvement in performance of high school students (Salomon, Globerson, & Guterman, 1989); and the technologies for creating an intelligent tutoring system have improved a great deal since then.

ITs use a variety of approaches like adapting to learners needs, adjusting the grain size of learning units (from simple to complex), promoting transfer of skills to different contexts, allowing students to abstract skills, modeling good problem solving approaches, providing appropriate feedback (based on students' input/responses), and adapting to changing conditions (adapted from Andersen et al., 1995).

Creating ITs usually requires the identification of learning tasks, creation of an ideal approach to learn the tasks (using task analysis, think-aloud problem solving), creation of possible tutor-student interactions (using expert tutors who are knowledgeable in the subject as well as tutoring), and programming the interactions into a computer system (Anderson et al., 1995). The computer systems that support these ITs include parsers (that process the student input), meaning making routines (that categorize students' responses), identification of the current state of the tutoring interactions, rules that govern the appropriate tutor responses, and the visible interface.

RESEARCH ON WEB-BASED TRAINING FOR THE STRUCTURE STRATEGY

A previous study by Meyer et al. (2002) provided valuable information on students working in web-based environments. That research study provided instruction on the Structure Strategy using static web-pages. Students were asked questions and their responses were emailed to human tutors who were trained in assessing the students' responses and providing email feedback. Some very important findings from this study have influenced the design of our ITSS significantly. They are:

- Training human tutors is expensive and human tutors are not always consistent.
- Students require extrinsic motivation and monitoring to complete lessons outside the traditional classroom environment.
- Students frequently skip ahead and do not read many of the passages and instructions (This has been reported in previous studies of multi-media learning (Jacobson, Maouri, Mishra, & Kolar, 1995).
- Students made lots of spelling errors in their typing and also wrote short responses.
- Students with low prior knowledge and poor reading skills (as assessed by the teachers and test scores) appeared to be discouraged by numerous attempts to complete their tasks. This was also reported by one of the consultants on our project who is a 5th grade teacher for many years.

This research study was the primary source of information for our lesson choices, modeling, interaction design, student responses in Latent Semantic Indexing

(Intelligence), and feedback.

DESIGN THEMES FOR ITSS

Based on the research reviewed above, we chose the following design themes for the ITSS environment:

1. The interface must engage student to read and practice using the SS – current topics of interest, age appropriate questions, and constructive responses.
2. The interface is designed to project a "learning" environment and not a game-like "play" environment.
3. Students' visual channels should not be overloaded by multiple windows and texts. Narration can be one method to encourage students to listen and read along.
4. Assessment should include multiple constructs like finding signaling words, writing main ideas, recalling details, and using text structures to organize recall.
5. Feedback should be constructive.
6. Students must be able to interact with the ITSS as a consistent tutoring environment similar to working with a trained tutor.
7. Students should not be discouraged by too many tries.
8. Students should not have the opportunity to skip over sections especially when they are not able to use the SS effectively.

The system we created using these design themes, ITSS, has the following features:

1. Infrastructure – the system we designed had to support at least 500 concurrent users from school districts. The system had to be easily accessible, interactive, and allow video/audio/animation. To accomplish this goal we chose a .NET platform with Flash to create the animations and interactions. The system resides on a Windows 2003 server with a SQL Server database storing all the interactions and assessment (Dell Dual Processor Server with Microsoft Windows Server 2003, database – SQLserver 2000, Webserver – IIS, Sun Solaris Server for Latent Semantic Indexing).
2. Intelligence - The "intelligence" of the system comes from using Latent Semantic Indexing (LSI) software that learns from each interaction with a student. For example, the system is loaded with all the responses from students in the pilot study (The good responses as well as the poor responses). The database maintains scores for all these responses. When a new student response comes into the system, it is checked against existing responses and if it is an 80% match to an existing response then we know how to score the response. If there is no match in the LSI space, we score the response using keywords and then incorporate the new response into the LSI space for future use.
3. Interface – Figure 1 shows the interface for ITSS with a "tutor" affordance/metaphor and the screens looking like a book. Color coded tabs on the "book" show each structure as the student progresses. Five tabs for each structure (Comparison, Problem/Solution, Cause/Effect, Description, and Listing) light up as they start work on that structure. As they complete approximately 10 lessons for each structure, the tab fills up with colors to show student progress in learning the structure.
4. Individualized - Students will progress through lessons at their own pace (with unique usernames and passwords) and can start at the lesson where they left off during the previous session. Additionally, any students completing all the text structures can transition to the Pennsylvania System of School Assessment (PSSA) tests for 5th and 8th grade that have been adapted to work in the ITSS

system.

5. Interactions – Students are given earphones to listen to the narration of the lessons and respond to questions by clicking on words or typing answers.
6. Software Agent with Narration- Students interact with a software agent who is a Caucasian male with a voice narrated by a young adult.
7. Gradually Increasing Complexity - Allow students to apply the SS in text passages of varying complexity. The system also shows students how text structures can be embedded within another structure.
8. ITSS Model - Figure 2 shows the model of the intelligent tutoring system. The system starts operations with the login of the user. The database verifies the username and password and then controls the system interaction with the user. Using the human-modeled lessons as the basis for interactions, the system presents the user with modeling, readings, questions, and responses. The student interacts with the system by clicking on buttons, words, or typing responses. When the system receives the student responses, it checks spelling and replaces words, evaluates the response based on the questions, user's try (maximum tries is usually three), keyword matches against the database, and finally a similarity match against the LSI space. The keyword matches with the database use recursive procedures to traverse tree structures for each reading passage.
9. Navigation - Navigation buttons to move to the next page do not appear on the screen until the student has completed listening to the narration.
10. Documentation - User documentation is available for the students and teachers. This documentation includes a user guide and "Keys" for each text structure to server as a job aid when the student uses the system or for use during their regular classes.
11. Diagnostic Reports - The system is capable of producing diagnostic reports for teachers and students to track their progress as well as comprehension.

Figure 1. ITSS Interface

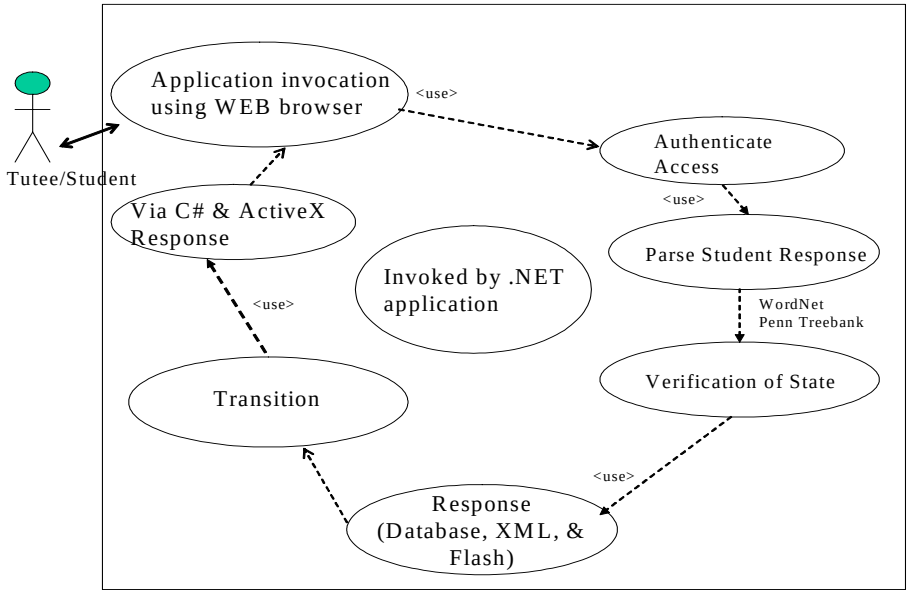

Figure 2. Interactions in ITSS

STEPS TO IMPLEMENTING THE ITSS

1. Lessons for the ITSS are adapted from Meyer et al. (2002) with new lessons with current interest added to motivate students. Approximately 10 lessons for six basic expository text structures (description, sequence, cause/effect, problem/solution, comparison, and listing) have been developed. Reading passages for each lesson were chosen based on text structure, good use of signaling words, varying complexity, and motivation. Passages also varied from single sentences that allow the student to focus on single signaling words to very complex prose that have nested text structures that contain hierarchies and many signaling words.
2. Modeling of Interactions was created by combining data from previous research study by Dr. Meyer and a 5th grade teacher who modeled the lessons. A detailed lesson plan with storyboard was created combining passages, explanations, questions, and answers.
3. Animations and interactions were created based on the storyboard using Flash™ and narration. All web-pages present information and use C# programs to collect and process responses from students. Narrations are created by a young adult working with the design team.
4. Mimicking a human-tutor, ITSS uses a human-like agent to make the interface more realistic. All the human expressions and gestures are created in Truespace™ and saved as Flash™ files. The tutor is a Caucasian male with three dimensional modeling of over facial expressions (ranging from negative, re-assurance, smiling, nodding, and prompting). The tutor also has narrated voice responses programmed with the facial expressions.
5. Interactions between students and ITSS were adapted using the log files of all the interactions between the students and tutors the Meyer et al. (2002) study. These

interactions were reviewed and coded by trained independent raters. The scores for main idea, signaling words, text structure, details, and intrusions were coded into the database and linked to the LSI space.

6. Assessment and scoring of student responses were based on the similarity to existing responses and/or keyword matches to the reading passages. The assessment was programmed using a recursive tree to track the important parts of the passages. For example, Figure 3 shows the tree for the passage on Elephants.
7. Feedback and responses to students were chosen based on their scores. When a student provides a good response with scores of over 70% on the main idea, signaling word, details, and text structure, they are shown an animated agent saying "Good Job". When one or more of the scores was lower, the agent gave them detail hints on what they need to improve.
8. Minimizing frustration with the ITSS, we have incorporated a three-try limit to each question. After each try the learner is given more detailed hints on correcting their work. If the student fails to improve their response after the third try they are shown the correct answer and the system transitions them to the next task.
9. Motivational components currently included in the design are positive comments by the software agent ("You are really doing well"), referring to the student as "Intelligent" when they complete their tasks with good scores, and progress indicators on the tabs of the book interface.

Elephants

Two different kinds of elephants exist today; these two types are the African elephant and the Indian elephant. These interesting creatures differ dramatically in ears, backs, and how long they live. African elephants have very large ears. Their backs arch down in the middle. African elephants live 50 to 60 years.

Indian elephants have small ears. The backs of the Indian elephants arch up in the middle. They live 70 to 80 years.

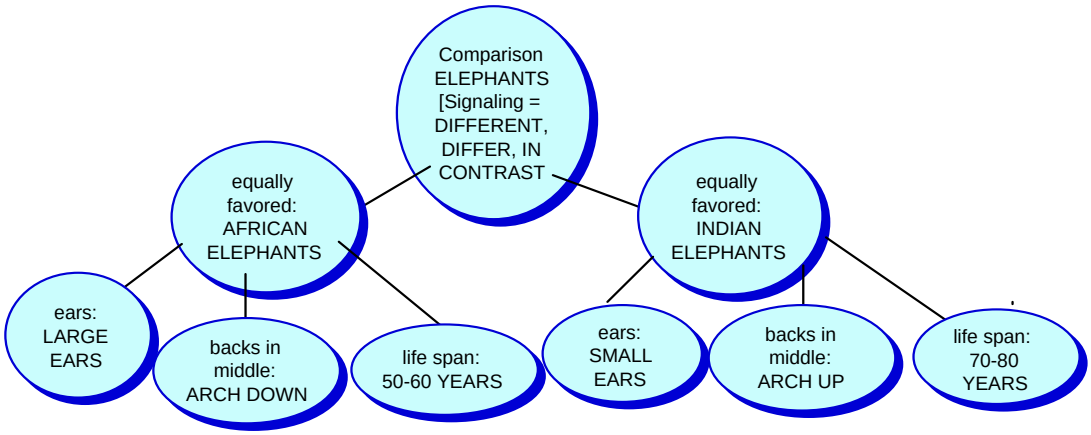

Figure 3. Elephant Tree

PILOT TEST OF THE ITSS

Our ITSS system was pilot tested to evaluate the quality of the interface, interactions, and learning environment. Another goal of the pilot test was to identify reading preferences of 5th and 7th grade students. Extended testing of the ITSS is scheduled to begin in shortly.

Fifteen participants from grades 4 through 8 volunteered to participate. Participants completed the informed consent forms, demographic survey, a 21-item (five-point Likert scale) *Computer use and opinion questionnaire* (Krauss & Hoyer, 1984; Meyer & Poon, 1997), a 23-item self-efficacy questionnaire (4-point Likert scale; reliability = .86) (Sherer et al., 1982), and a 20-item *Motivation to Read* profile (Gambrell, Palmer, Codling, & Mazzoni, 1996). Participants then completed either Form A or Form B (counterbalanced) researcher designed pre test measure of reading comprehension. The test had recall, writing a title for a passage, and cloze tasks. After the completion of these measures students viewed and interacted with the ITSS sample lessons 1-3 (Comparison Structure). Students were also asked to review the selection of passages and state whether they would be interested in reading about those topics. At the conclusion of their interactions students completed the post test measure and were interviewed by the researcher.

The interview questions were open ended and were directed at their opinion about IT (the intelligent tutor), sounds, passages, and affordances of the system. The researcher also maintained a log of time to complete tasks like finding signaling words, typing responses, and clicking on buttons.

Additionally, two reviews were conducted by consultants and focus groups to evaluate the usability, effectiveness, motivation, and overall flow of interactions in the ITSS. First, two subject matter experts, expert tutors, two technical experts, and 10 undergraduate students reviewed the content, technical features, and layout of the ITSS. The following elements of the ITSS were reviewed: passage selections, interaction criteria, animated agent design, technical specifications, modeling, and feedback. Second, one researcher conducted observations of participants using the ITSS. The observation included a modified Click Response Time Test and Memory Test (Tullis, et al., 2000). Logged interactions of the participants were reviewed for consistency as well as learning outcomes.

The following are sample questions from each research area:

1. *Aesthetics, Consistency, and Standards*
    a. Are the actions, terms, icons, and menus consistent throughout the lessons?
    b. Are colors, layout and fonts consistent and visually pleasing?
    c. Is the text size and denseness readable?
    d. Is the IT personality friendly and engaging?
    e. Was the sound quality good?
    f. Were the directions from IT understandable?
    g. Was the interaction style of IT – point to text, requesting input, and feedback useful?
    h. Are the selections, user input, feedback, and options consistent and understandable?
    i. Does the level of consistency and standards satisfy the needs of a 5th-7th grade audience?
    j. Does the screen layout focus attention on the important areas?
2. *Recognition vs. Recall*
    a. Does the “Tutor” metaphor get conveyed effectively in the system?

   b. Does the human-like tutor help you feel at ease with the system?
   c. Does the human-like tutor speed up recognition and encourage you to learn from the system?

3. *Visibility of System Status*
   a. Did you feel that you were in control of the system?
   b. Did you know how much of the lesson you had completed?
   c. Was the system response time good?
   d. What caught your attention on the first page of ITSS you saw today?
4. *Providing Informative Feedback*
   a. Was the feedback from IT informative?
   b. Were you able to understand the feedback and act on it?
   c. Were you able to listen to the feedback again?
5. *User Control and Freedom*
   a. Were you able to undo any accidental actions?
   b. Were you able to navigate through the ITSS easily?
   c. Were you feeling confident in your ability to use the ITSS?
6. *Error Prevention and Handling*
   a. Were the error messages useful to you?
   b. What caused error messages to appear?
   c. Did the system lock-up or stop functioning at any time?
   d. Did you know how to recover from the error?
7. *Help and Documentation*
   a. Were the help and documentation sections useful?
   b. Did the written guide help in navigating the ITSS?
   c. Did you use the "keys"?
   d. How useful were the "keys"?

PILOT TEST RESULTS

Participants of all age groups expressed positive attitudes towards IT. Two participants suggested that IT looked like a "football player". Four participants said that they liked working with a "person" suggesting that they related to the software agent as a human. Participants also said they liked the sounds. Four participants from 7th and 8th grade stated that they did not like having the passages read to them.

Most importantly, all participants had no prior knowledge of text structure and what a main idea is. Two participants from 7th grade who have very high standardized reading scores were surprised that text structure was useful in remembering more information. They were quick to ask what other text structures were there and what types of signaling words are used.

All participants found the narration and instructions understandable but some experienced difficulty in just listening to the instructions (when the instructions did not appear on the page). An analysis of keystrokes and time for performing tasks found that there were no major problems with the interface. Students progressed along the lessons with no problem spots.

All participants took longer times to type their responses than when they had to write responses on a sheet of paper. In spite of this timing factor, each lesson lasted approximately 40 minutes. The design team originally estimated times for each lesson to be between 20 to 40 minutes.

One participant described a scenario in his school where a computer program was introduced to improve computer usage like browsing the Internet. The participant reported that a few students in the group class started trying to thwart the system and

making negative comments. He said that the momentum for the negative comments grew to the point where almost all students participating in the lessons were not interested in learning and instead played games with the system trying to break it.

During the ITSS pilot testing participants were shown a list of titles of passages for lessons with parallel choice lessons. They were asked to choose the passages they would prefer to read or suggest alternatives. Older participants were more vocal in their lack of interest in the chosen reading passages like animals and history. Instead, they suggested passages on sports and music industry figures. All participants suggested that they would read the passages that were currently available, but preferred to read about sports and music industry figures.

Based on pilot results we have made the following modifications to the ITSS system:

- New passages have been added to motivate the students to use the structure strategy. For example, new passages have been added comparing Olympic athletes.
- More on-screen instructions were added to aid the students in completing tasks like choosing the number of signaling words or writing responses.
- More point and click questions were included to minimize the typing required (for example, clicking on signaling words instead of typing them).
- Additional motivational elements are being discussed. For example, adding a game at the end of each text structure as a reward for completing the tasks well.

CONCLUSION

The preliminary phase of our project is underway and has concentrated on the research and design of the ITSS, pilot study, modifications, and final preparation for the large-scale study is planned. Fifth and seventh grade students will spend two to three class sessions of 30 to 40 minutes in duration each week for seven months working on ITSS during the regular school day. The year spent in development, pilot testing, and final preparation was critical in preparing a quality system ready for further testing of components when incorporated into a school district's curriculum.

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