SOFTWARE ASSISTANT FOR STUDENTS WITH LEARNING DISABILITIES

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Abstract: Social and professional integration of persons with disabilities is a major challenge faced by many communities. In particular, teaching or training such persons is a very demanding task. This paper presents details of the specification and design of a new software tool aimed at assisting the learning process of students with learning disabilities. Using a four-step problem solving strategy, the tool helps the students to obtain a good grasp of the problem and assists them in expressing the problem in mathematical terms. A survey of related projects as well as directions of future work are also presented in the paper.

Keywords: assistive technology, learning disabilities, cognitive strategies, software tool, use cases, UML.

1. INTRODUCTION

Modern assistive technology has the goals of addressing the needs of persons with disabilities and providing them with adequate access to a comprehensive range of software tools. Teaching or training people with disabilities is still a very demanding task, a major challenge faced by many countries, communities, and organizations. Unfortunately, learning disabilities represent only one of the many problems that remain to be solved in order to improve the work, study, professional advancement, and social participation of disabled people.

A thorough review of the literature on technology-based learning practices for students with disabilities has led us to the discovery of some significant results and observations. For example, several reports consulted pointed out that the use of computerized study guides, in particular hypertext and hypermedia study guides, have led to substantial improvement of students' comprehension. Also, the reports highlighted the importance of effective teaching principles such as self-paced, sequenced lessons, positive feedback, and redirecting students to previous lessons (Maccini, *et al.,* 2002).

Regarding technology-based practices for middle and high school students, some noteworthy observations are as follows. Reading and writing have traditionally been major areas of concentration due to the fact that numerous students with learning disabilities have often shown problems in these areas even though their level of intelligence is average or above average. Many such students have difficulties with respect to basic spelling and grammar skills. Also, they have displayed problems when tackling the tasks of planning and organizing their written work. Furthermore, handwriting is also a challenge for them and a major cause for less and lower quality written work being produced by children with learning disabilities (as compared with same-age colleagues who are not disabled). Lewis (1998)

describes assistive technology as having two purposes: "to build on individual strengths, and to compensate for disabilities". Forgrave (2002) highlights three areas that seem very promising for students in middle and upper grades: speech synthesis programs, organizational software, and voice recognition software.

In what regards learning of mathematics, the fact that current technology offers help in computing math (via calculators and computers) but not with problem solving does not help the situation (Gallagher-Landi, 2001). Studies have shown that problems such as attention deficits, memory lapses, auditory processing difficulties, visual spatial difficulties, motor disabilities, and information processing deficits contribute to poor problem solving by students with learning disabilities. These students also do not have intuitive strategies to solve word problems. As pointed out by the author, "studies have also indicated that students with learning disabilities rely primarily on checking and computing strategies and tend not to use higher order, problem representation strategies such as paraphrasing, visualizing, and hypothesizing" (Gallagher-Landi, 2001).

On a positive note, other studies have revealed that students with learning disabilities can improve their learning of solving word-problems by using computer-based tutorials (Shiah, *et al.*, 1995). Furthermore, recent research has indicated that a solution to improving the performance of students with learning disabilities on word problems can be provided by using cognitive strategies (Gallagher-Landi, 2001). Thus, these students could benefit from training that emphasizes problem representation strategies. The ability to think clearly and efficiently about a problem, "picture it" in the mind, and express it in the student's own words are key aspects of the problem solving process. The educators' challenge is to teach these skills to students with learning disabilities such that they become capable to solve problems efficiently.

Also according to recent research, many methods have been tried with students. For example, Irish (2002) tried instructional strategies embedded in a software application. The author used a multimedia software program to teach a mnemonic strategy to learn multiplication facts. Students with disabilities benefit from adaptive calculators that can talk, problem-solving environments using computers, drill and practice (again, using the computer) and software tools for data visualization.

The particular solution (project) presented in this paper converts the four-step problem representation strategy proposed by Gallagher-Landi (2001) into a software solution. A math problem is presented in the form of a story. The challenge is to assist the students in obtaining a good grasp of the problem and to aid them in expressing the problem in mathematical terms. This project is unique in that the strategy is applied in using a storybook setting that includes graphics, colors, and friendly virtual characters in order to increase students' motivation and interest.

In its remaining part, this paper is organized as follows: Section 2 outlines the cognitive strategy (Gallagher-Landi, 2001) used in the proposed tool, Section 3 presents an overview of the tool in terms of functionality and user interface features, Section 4 gives details on the software tool's requirements specification, Section 5 illustrates its use case modeling and Section 6 provides pointers to future work as well as several concluding remarks.

2. OUTLINE OF THE STRATEGY FOLLOWED

The software assistant developed, referred to simply (and tentatively) as Math Helper, is written in C# and runs on WindowsXP. This project is an attempt to create a software tool that helps students with learning disabilities study mathematics. These students are usually characterized by poor problem solving skills. Nevertheless, as indicated previously, using cognitive strategies could improve the performance of these students. Furthermore, it is considered likely that the students would benefit from training that emphasizes problem representation strategies. Thus, the purpose of the project was to support with a computer program such a cognitive strategy in order to help students with disabilities solve word problems more effectively. The four-step problem solving strategy proposed by Gallagher-Landi (2001) and used in our Software is outlined in Figure 1.

Step 1: Paraphrase – express the problem in your own words *Skill 1*: Underline important information *Skill 2*: Present the problem in your own words
Step 2: Visualize the problem using diagrams or pictures *Skill 1*: Draw a diagram or picture
Step 3: Hypothesize in terms of number of steps, operations, and equations needed to solve the problem *Skill 1*: Decide how many steps are needed
Step 4: Estimate (predict the answer) *Skill 1*: Estimate the correct solution

Fig. 1. The four steps of the problem representation strategy [based on (Gallagher-Landi, 2001)]

In Step 1, when the student paraphrases (underlines relevant information and restates the problem in his or her own words), he or she can better understand the problem and become more capable of identifying those pieces of information that are important for solving the problem. In Step 2, using

drawings and diagrams to depict word problems is useful for the student to more precisely perceive the fundamental structure of the problem. In addition, it helps the student to make connections between the problem's visual model and known mathematical symbols. In Step 3, the students are required to correctly identify the operations needed for solving the problem. They are also required to recognize the similarities and differences between word problems and correctly identify the problem's type (for example, whether the problem involves addition/subtraction and/or multiplication/division) In Step 4, the estimation of the problem's correct solution (answer) is required. By enhancing their estimation skills, the students can indeed become independent problem solvers.

The four steps (paraphrasing, visualization, hypothesizing, and estimation) of this cognitive strategy are applied in Math Helper using a storybook interface metaphor. Solving the problem using such format takes some of the hard work away from the students. The students are led through the different steps explicitly, so they do not have to memorize the steps. A word problem is presented as a story; for example, at Christmas time two children need to find out if they have enough money to buy gifts. The students who use Math Helper are asked to help solve this problem. They are led through each step, immediate feedback is provided to guide the problem solving process, and correct answers are available when requested. By using this strategy explicitly, it is hoped that the students will acquire good problem-solving skills.

It is assumed that the intended users of Math Helper have the required skills and vocabulary to read and understand word problems. The software has been designed to be used by third and fourth grade students who experience difficulties in solving math word problems.

3. OVERVIEW OF THE SOFTWARE TOOL

Math Helper has three modes of operation, namely the *braille mode*, the *speech mode* and *the regular mode*. The tool can accommodate children with visual impairments, deafness, learning disabilities, cerebral palsy, and brain injury. It incorporates a touch screen and Intellikeys. Instruction is provided, for the moment, in two languages, English and Spanish. There is also a virtual character called Bob the Bunny that children can ask for help in solving problems. However, the prototype is only partially implemented and supports only the cognitive strategy part of the model.

The welcome screen presents to the user the various facilities, modes of operation, and options that teachers can choose from to set up each child's individual learning environment. After the environment is defined, the next screen displays the topics teachers can choose from based on the child's grade level. For a given student, the teacher can select a specific lesson as well as a level of difficulty (easy, medium, or difficult).

Math Helper is built on the assumption that children perceive a graphics-intensive, colorful environment as welcoming. This would be a non-threatening environment where they can study at their own pace. It is also assumed that the students would prefer studying in their own native language (hence the inclusion of both English and Spanish), and enjoy working in a personalized environment that is adapts to their current level of performance.

This project supports lessons on word problems. A word problem is set in the framework of a story. For example, considering again the "Christmas time" setting, two children have to buy Christmas gifts for the family. They have to calculate how much money they have and how much they can spend on gifts. For children with learning disabilities, describing this situation in mathematical terms is very difficult. Thus, a strategy with explicit steps is provided. Math Helper takes the student through the various stages of solving the problem, and therefore helps reducing the students' problem-solving burden. The students do not have to memorize the steps involved and, at each step, immediate feedback is provided such that they are not left wondering what to do next. Moreover, they can ask for help from Bob the Bunny and get the answer if they want to. The software itself provides hints along the way by giving answers to some parts of the questions.

Conceptual models of instruction, conversing and manipulating and navigating (Preece, *et al.*, 2002) are used in Math Helper. The *instruction mode* is used by the student to print, edit, save, and so forth. The *conversing mode* is used to ask for help from the bunny and to obtain hints and answers from the program. *Manipulation* and *navigation* are used by the teacher to select various settings and choose lessons. The students also use this conceptual model when navigating from one page to the next as well as when asking for help. The interface metaphor of a storybook was used; the tool uses a narrative technique similar to that emplyed in story telling and the tool's interface is filled with images, sounds and colors. The story has a beginning when the problem is introduced and an end when the problem is solved.

4. REQUIREMENTS SPECIFICATION

In the following, using notational style proposed by Arlow and Neustadt (2002), the most important requirements for Math Helper software assistant, both functional and non-functional, are presented.

4.1. Functional Requirements

Some of the relevant functional requirements for the Math Helper software tool are listed below.

The Math Helper shall:

R01 Allow the teacher to log in.
R02 Allow the teacher to select the mode, whether Braille, speech or regular.
R03 Allow the teacher to add on the appropriate support.
R04 Allow the teacher to enable the use of touch screens.
R05 Allow the teacher to select one of two languages for operation (English or Spanish)
R06 Allow the teacher to set up alternative input using Intellikeys.
R07 Allow the teacher to select the lesson for study.
R08 Allow the student to set the "display score" option.
R09 Allow the optional use of computer reading of text.
R10 Provide Braille printout of all text.
R11 Provide large text software toggle for screen.
R12 Provide large text printouts.
R13 Teach a range of skills from basic to complex by presenting math concepts and problems at multiple difficulty levels.
R14 Provide feedback on student answers.
R15 Provide the correct answers.
R16 Provide a virtual character (a bunny called Bob) that helps the student with certain questions.
R17 Keep track of student scores and display it when asked.
R18 Provide captioned text to accompany any audio media.
R19 Allow access to the Internet to selected websites.

4.2. Non-Functional Requirements

The following are excerpts from Math Helper's list of non-functional requirements.

The Math Helper shall:

T01 Be written in Visual C#.
T02 Have a Microsoft Windows based interface.
T03 Quickly respond to commands.
T04 Be connected to the Internet.
T05 Allow at least ten students to log in at the same time.
T06 Allow at least one teacher to log in at the same time.
T07 Not disclose information about students to other students.

5. USE CASE MODELING

The entire functionality of the Math Helper software is represented in the use case diagram shown in Figure 2. A correspondence between the functional requirements listed in subsection 4.1 and the use cases shown in the use case diagram can be easily established. For illustration purposes three of Math Helper use cases are shown in a simplified form in Figures 3, 4 and 5.

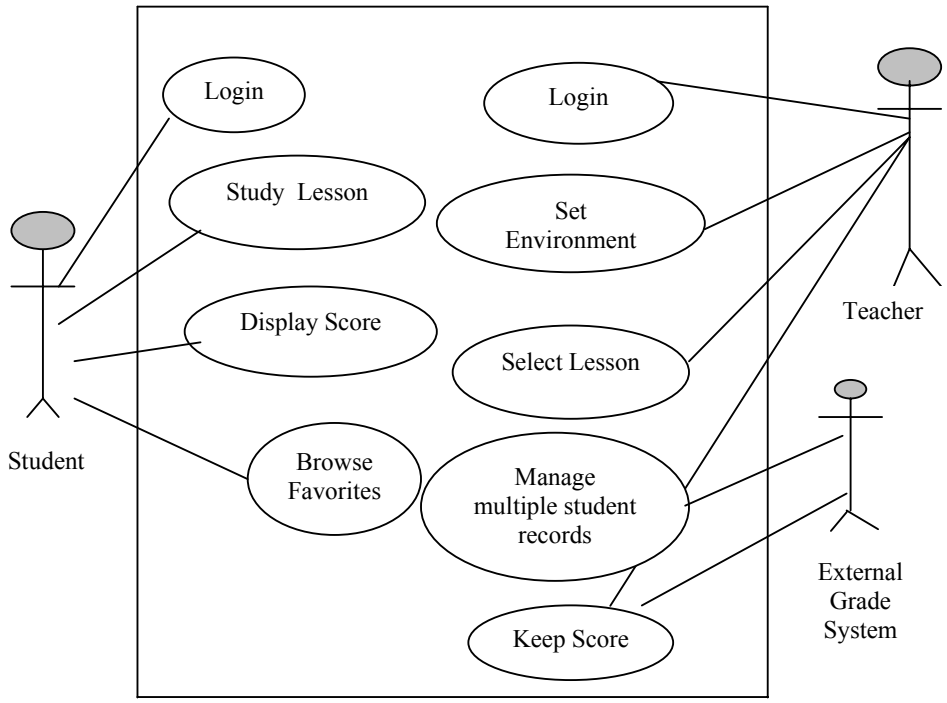

Fig. 2. Use case diagram of the Math Helper software

Use Case: Set Environment
ID: UC2
Actors: Student with disability Teacher
Preconditions: Student is logged on the system Teacher is logged on to the system
Flow of events: 1. The teacher selects the mode (Braille, speech, or regular) 2. The teacher selects the appropriate supports from the option "Add supports" 3. The teacher selects the language for communication, whether English or Spanish 4. The teacher selects the option to set touch screen functionality or not 5. The teacher selects the option to use Intellikeys or not 6. The teacher sets the difficulty level (1, 2 or 3) 7. The student decides whether to choose the option "display score" or not
Post conditions: The learning environment is set

Fig. 3. Math Helper Set Environment use case

The Set Environment use case shown in Figure 3 describes how the teacher can set the learning environment by choosing for the student the appropriate options, while the Select Lesson use case presented in Figure 4 specifies how the teacher can select the appropriate lesson.

Use Case: Select Lesson
ID: UC3
Actors: Student with disability Teacher
Preconditions: 1. Student is logged on the system 2. The learning environment is set
Flow of events: 1. The teacher clicks on the "next" button to go to the second screen. 2. On the second screen, the teacher selects the grade level from a drop down list of grade levels 3. The teacher selects a topic from a drop down list of topics 4. The teacher selects a particular lesson from a drop down list of lessons
Post conditions: A lesson is selected for study

Fig. 4. Math Helper Select Lesson use case

Use Case: Study Lesson
ID: UC7
Actors: Student with disability Teacher
Preconditions: 1. The student is logged on the system 2. The teacher has selected the lesson for study
Flow of events: The use case starts when for every unit of information in the lesson: 1. The system presents the unit and poses a question on the material presented 1.1 If the student selects the right answer: 1.1.1The system provides feedback of the form "well done" 1.1.2 The system increments the score 1.1.3 The next unit of information is presented 1.2 If the student selects the wrong answer: 1.2.1 Student is provided with appropriate feedback on the verity of the answer 1.2.2 He can obtain the right answer by clicking on the "get answer" button 1.3 If the student does not answer the question: 1.3.1 He can ask the virtual character (the bunny) for help 1.3.2 He can get the right answer by clicking on the "get answer" button 1.3.3 The system displays the next unit of information
2. At the end of the lesson the system displays student scores
Post conditions: The student completes one lesson

Fig. 5. Math Helper Study Lesson use case

Furthermore, the Study Lesson use case shown in Figure 5 describes how the student can navigate through the lesson.

6. FUTURE WORK AND CONCLUSIONS

Various enhancements are possible for this project. For example, the users could benefit from having access to the Internet (although planned, this has not been yet implemented). With a web-based software solution, the students could connect to sites recommended by the teacher to study and research various topics. Also, math games could be added on to motivate students and to provide practice in basic skills and problem solving. A database of student records would be helpful to the teacher to keep track of student progress and enable curriculum-based measurement. Entries in the database could consist of the date, the number of problems solved, the grade the student received, and so forth. Furthermore, the software could

incorporate various problem solving strategies and support different learning modalities. Yet another enhancement would be the use the software to monitor student performance as performed usually in curriculum-based measurement.

All students, including those with learning disabilities, require problem-solving skills to live in today's modern world. The goal of Math Helper, the software tool presented in this paper, is to impart these skills to the students.

The tool incorporates several effective teaching principles including corrective and positive feedback, re-routing of students to difficult concepts, and provisions for multiple opportunities for response such that students are encouraged to become active participants. A four-step problem solving strategy is used, taking in consideration elements of cognitive science and child pedagogy. Students are constantly and explicitly guided through each step of the strategy. Each step involves performing one or more particular, clearly defined activities – for example, in step one, paraphrasing, the student restates the problem in his or her own words. These activities help the student better understand the steps he or she is following in order to develop a correct solution for the problem.

It is hoped that this approach will enable the students to make the strategy their own. In the proposed Math Helper software, sound and graphics are included to stir curiosity and increase motivation. Also, the strategy is presented in a story format to add interest. Students are invited to select the fonts and the colors that they the are most comfortable with. This feature could be particularly convenient for students with dyslexia. A virtual character, a bunny called Bob, is included in the environment to help the students in their work. Thus, it is hoped that a "live", friendly and interesting environment is created to motivate the students. The students can go through the problem solving steps at their own pace and prompt feedback and suitable praise is provided during each step.

This paper has presented only a part of a complex project that aims to offer assistive technology to support the learning of persons with disabilities. This challenge, the authors believe, opens a vast area of research and development and could lead to very rewarding results.

In summary, the work presented in this paper has the following contributions:

- Identification of several major directions of development in the area of software support for students with learning disabilities;
- Proposal of software tool that incorporates the four-step cognitive strategy process described in (Gallagher-Landi, 2001);
- Design and implementation of the software tool, thus illustrating the concepts investigated and the four-step process followed.

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