Mathematics for all: a Game-Based Learning Environment for Visually Impaired Students

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***Abstract*—Visually impaired students who reach higher education have a preference for human sciences. The difficulties felt with courses such as mathematics, during their school years, may lead them to abandon the possibility of pursuing higher education in exact sciences and engineering courses. We propose a game-based learning environment that can be used in class and at home by visually impaired students. The game was developed for middle school mathematics but can be adapted for primary school and secondary school. The main goal of the game is to help and motivate blind teenage students to learn and like mathematics.**

The graphics are designed for low vision students but to guarantee accessibility to blind students, the game can be played without the need to see the graphics. All the features are complemented with audio and the game uses 2D spatialized audio. Having graphics also contributes to the integration of visually impaired students with their sighted colleagues.

The game was tested in two schools with blind and low vision children. Both teachers and students were very enthusiastic with the game and gave us very positive feedback. The results of the test suggest that the game can have a positive influence in mathematics performance.

***Keywords*-game-based learning; education for the blind; educational computer game**

I. Introduction

The past few years have witnessed a change of opinion about the pros and cons of video games. While previously these were mainly seen as an addictive way of entertainment for youngsters, with several negative consequences, now people have been progressively starting to understand the good influence that well designed video games can have. In fact, it has been shown that video games can have a positive effect on school performance [1].

In this context, several educational computer games have been proposed (see section II). With these games, students feel more motivated and engaged in the learning process, which contributes to an increase of the effort they put on learning the school curriculum. In addition, the games also contribute to the acquisition of other skills, such as problem resolution strategies, data interpretation, problem analysis, ability to create mental representations of abstract concepts, among others [2], [3].

Yet, in spite of all the benefits offered by educational computer games, only seldom blind students are able to take advantage of these games. The main reason is that most educational software is designed for sighted students, having a strong visual component. However it would be desirable that visually impaired students could have access to these technologies. The fact that nowadays blind students attend inclusive schools emphasizes the need to apply new technologies to aid these students. Another great advantage of educational games for blind students is to contribute for their integration with their sighted colleagues and ultimately in society.

As a response to this problem, we propose a computer math game for visually impaired students that can also be played by sighted students. This game provides a fun environment with plenty opportunities to exercise mathematical reasoning through questions and problems. With this game, we hope to help blind students (and others) enjoy learning mathematics and to broaden their chances of reaching higher education in exact sciences and engineering courses.

To promote learning the student has feedback on his/her answers. More specifically, when the given answer is wrong, the game gives a written and spoken explanation on how to solve that particular math problem.

In order to keep the students engaged and motivated, the game uses an interesting story appropriate for the age group of middle school students. Moreover, the game has a reward system that depends on the rate of correct math answers the student gives.

Since the game is especially designed for visually impaired students, the game can be played without the need to see the graphics. Therefore, sound plays an important role in the game. All the features are complemented with voiced and unvoiced audio and the game uses 2D spatialized audio.

The graphics are designed for low vision students. The scenes are simple, with few details and without overlapped objects. The characters are bigger than objects in the scene and are easily identified due to their size and bright colors.

Having graphics also contributes to the integration of blind and low vision students with their sighted colleagues, as the game can be played by all students individually or in group.

The game was tested by 9th grade students from two inclusive schools. The results of the tests suggest that the game can have a good influence on mathematics performance (section IV). In addition, we had very positive reactions from both visually impaired students and their math teachers. Students were quite excited with this game because they were able to play it by themselves, without the need of assistance from a sighted colleague, teacher or family member. The teachers also showed great interest in the game and observed it could be a great tool to make the students do some math exercises.

In the next section (section II) we will review some related work. Section III explores the game, while section IV discusses the results obtained with visually impaired students. The last section (section V) presents the conclusions and future work.

II. Related Work

Educational games can follow several methodologies. Intelligent tutoring systems are among the possible methodologies. These systems have an intelligent tutor that interacts with the students giving them advice or explanations. An example of such a game is the virtual reality geography game created by Virvou at al. [4]. In this game, students have to navigate in a virtual world of dungeons and castles while answering geography questions. This game has a strong educational component that is presented in a captivating way. For instance, there are animated tutors that give advice or clues to the player and there is a reward system that depends on the answers given. To stimulate the students to read (and absorb) the course's material that is presented at certain moments of the game, the questions are about that material.

There is also the option of having the story of the game to depend on the interactions with the player [5]. Dinis et al [6] have proposed a math game, with multiple choice questions which has an interactive story that evolves according to the player's choices.

A alternative to the question-answer learning methodology, is to use mini-games or challenges throughout the game. These can have different methods of interaction (such as drag-and-drop). As an example, "Learn English with Inspector Flops" is a mystery game for learning English in which the player practices listening and comprehension of English through several mini games that use different modes of interaction [7].

An interesting category of educational games are the adaptive games, such as the geometry game proposed by Ketamo [8]. In these games the difficulty can be adjusted according to the players preferences (using user defined options) or according to the players actions. For instance, in Ketamo's game, the difficulty of the questions is adjusted according to the rate of wrong answers and the time the user spends to answer the questions.

All the games mentioned above were designed for sighted players. To make a game accessible to visually impaired students it is important to use other non-visual modalities. AudioDoom is a game accessible to blind players, that is inspired in the classic DOOM game [9]. This game was created to test the hypothesis that a highly interactive acoustic environment can be used as a tool to stimulate and reinforce some abilities of blind children, like spatial representation. The game uses 3D spatialized audio and has a very rich acoustic environment. Its story is about an alien invasion to planet Earth, in which the player has to save the planet. To this end, the player coordinates haptic equipment (a joystick) guided by his/her perception of the sound's localization.

The purpose of the MOVA3D game is to help visually impaired children to improve their mobility skills [10]. It uses 3D spatialized audio and an special haptic controller that uses the clock method for orientation purposes (that is, directions according to the clock's hour hand).

Though it is not educational, Terraformers is a game that is worth mentioning. This game uses very rich audio [11] and demonstrates that audio can be used in several ways to convey information to the blind. It has several tools accessible to blind players through the use of voice and spatialized audio: it uses a system of voiced hierarchical menus to give access to objects, and 3D spatialized audio to simulate an acoustic compass and a sonar. The latter gives the perception of the localization (direction and distance) of objects. The game also simulates a GPS system that gives the exact coordinates of the objects in the game and the player's position.

AudioPuzzle is another non-educational game with interesting characteristics. This game uses the Android's haptic screen for input [12]. In this game the players have to solve a musical puzzle, in which the pieces are music segments. The players have to move the music pieces into the correct order using sliding movements.

Finally, it is also worth mentioning the TIM project [13]. This project explored the combination of specific hardware (a special designed keyboard) with a scripting language to adapt existing educational games for visually impaired children.

III. The game

The proposed game aims at being a useful tool for teaching and learning mathematics, while at the same time it guarantees that the students feel motivated and engaged in the process of learning and playing. For that reason, the game uses a captivating story, appropriate for the age group of middle school students (adapted from [14]). There are three main characters with whom the students can identify (they are in the same age group as the students and the main character is blind). The game consists of a treasure hunt with six adventure moments. The goal of the player is to lead the characters to the treasure site.

In order to combine learning with playing, the game has three modes: story mode, adventure mode and learning mode. These three modes follow the flow illustrated in fig. 1.

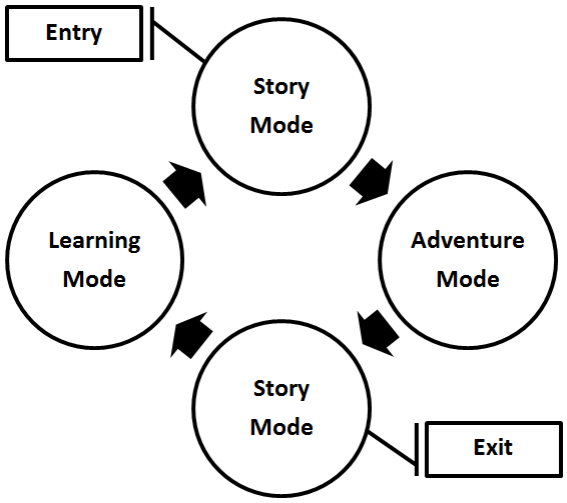

Fig. 1. The game's mode flow.

Fig. 2. An outdoor adventure mode scene (top) and an indoor story mode scene (bottom).

Story mode is used to develop the story. This is done through the dialogs of the characters. During adventure mode, the characters have to follow a set of clues in order to solve the mystery and eventually find the treasure. During this mode the job of the player is to move the main character through the scene to a specific location where a new clue will be found. Yet the access to new clues will be given only after the student answers a set of math question (learning mode). The top fig. 2 shows an adventure mode scene, where the main character is navigating through the city streets towards to the location where the next clue will be unveiled. The bottom fig. 2 shows a story mode scene, in which the characters are chatting about the math problems they will have to solve.

To make the game more fluid, adventure and learning mode never occur consecutively. In between these two modes, there is always a story mode: a pre-learning story mode and a post-learning story mode. When the characters reach the desired destination in adventure mode (such as taking the bus, or getting to a monument) the game changes to pre-learning story mode. At this mode, the characters have a conversation about the type of math problems they will have to solve in order to obtain the next clue. New clues are unveiled during post-learning story mode but the game changes to this mode only after the student answer a set of math questions in learning mode. The clues obtained during post-learning story mode consist of instruction on the next steps to follow and places to visit in order to unveil more clues and eventually find the treasure.

Each of the three modes has its own purpose and together they contribute to increase the student's motivation in playing and learning. The adventure mode is the most dynamic of the three modes. It gives the game an uncommon characteristic in this type of question-answer educational games, which is the active navigation challenging role (in the search of the next clue's site). The story mode is the simplest of the three modes. Its job is to give fluidity to the game, holding everything together and making all the moments of the game connect in a logical way. The learning mode is what gives this game educational characteristics. This mode is explored in more detail in section III-A.

A. *Learning mode*

It is during learning mode that students get the chance of reasoning about math problems, which are offered in the form of question-answer challenges. The game contains questions of three math modules from the 9th grade Portuguese mathematics curriculum (probabilities, proportionality and functions). There are six learning moments (two moments for each of the three modules). At each learning moment, the student is required to answer correctly four questions of a specific module in order to pass to the next post-learning story mode, in which a new clue will be unveiled. Students who fail a lot of questions will have to answer more questions in order to reach the desired number of correct answers. The four correct answers requirement guarantees that the minimum number of questions presented (24) is not too low and prevents the players from getting to the next mode without any reasoning effort. It also gives students who have more difficulties, plenty opportunities to practice and exercise math reasoning.

The questions are chosen randomly, so that the questions offered in each session vary. This discourages the students to memorize the answers (instead of understanding how to solve the math problems). In addition, the same question is never presented more than once in a given session.

The current game configuration contains a great variety of questions, with 80 questions from each of the three math modules mentioned above. Nonetheless, to help improving memory and training mathematical reasoning, we created variations

of the questions in order to obtain several similar questions. While these questions require the same type of reasoning, their answers differ, which avoids having the students memorize the answers. As an example, consider the following three questions.

- Let $f(x) = k/x$, with $x > 0$. What is the value of k such that f goes through point $P = (1/2, 4/9)$?
- Let $f(x) = k/x$, with $x > 0$. What is the value of k such that f goes through point $P = (5, -5)$?
- Let $f(x) = k/x$, with $x > 0$. What is the value of k such that f goes through point $P = (7/13, 5)$?

Even though the questions are similar, their answers are different ($2/9$, -25 and 35). In order to answer correctly, the student cannot memorize the answer, instead he/she needs to understand how to answer this type of questions. Repeating the questions in this way, will help students consolidate the modules.

To prevent the students from loosing motivation, it is important to have positive feedback on correct answers. Therefore, the game has a feedback system that says "Correct!" with an encouraging, cheerful voice whenever the student gives a correct answer. Furthermore, the game has a reward system that will be explained in section III-B. On the other hand, if the answer is wrong, the feedback system prompts "You missed it." with a non-happy voice. (In order to avoid discouraging students, we were also careful not to have a disappointed voice.)

Effective study techniques require practice but it is also important that the student understands how to solve correctly the questions he/she fails. Therefore, whenever the student fails a question, the feedback system explains (with voice and text) how to solve the question correctly.

B. The reward system

As mentioned before, once the student reaches learning mode, he/she will only get to the next mode once he/she answers correctly four questions. A student interested only in the navigation and story components of the game, can try to traverse the learning mode with little reasoning, giving careless answers until he/she is offered four easy questions that he/she can answer promptly without much effort. In order to stimulate students to give their best effort and strive to answer correctly to the questions, the game has a reward system.

This reward system consists of a simple scoring system which compensates better students who fail less questions. The final score depends on the total number of questions presented to the student:

$$final\,score = C * P/q\,,$$

where q is the total number of questions presented to the student (including those with correct and wrong answers), C is the total number of correct answers, and P is the number of points that each correct answer is worth. In the proposed game configuration, $P = 20$ and $C = 24$ because the student will only find the treasure once he/she answers correctly 24 questions (4 correct answers in 6 learning moments).

Students who fail no question (answering correctly the four questions presented at each learning moment), obtain the maximum score of 20. The more questions the students fail, the more questions they will have to answer in order to get over each learning moment. Therefore, students who fail more questions, will obtain lower scores.

With this simple scoring system, we aim at stimulating students to reason carefully about the answers they give. In addition we aim at motivating them to learn the math modules covered in the game.

C. Accessibility

Since some visually impaired students may have residual vision, the game has a simple visual interface. This has also another important goal, which is to encourage sighted students to play the game and, this way, contribute to the interaction of visually impaired and sighted students, and consequently the integration of visually impaired students in their classes.

We were careful to create a simple visual interface that was accessible to low vision students. The game characters are proportionally bigger than the objects in the scene (like buildings, cars, etc.) and they have bright color clothes and hair. The scenes are very simple, with few objects and no overlapping objects. In order to keep the visual interface simple, the scenes were created in 2D using a top-down perspective. Fig. 2 shows an outdoor (top) and an indoor (bottom) scene that exemplify these characteristics. In the bottom scene it is also possible to see a heads-up display (HUD) at the bottom of the screen, where the dialog is written.

Since the game was designed especially for visually impaired students, sound takes an important role and it is possible to play the game without seeing the graphics. All the menus, dialogs, questions, and other texts are complemented with voice recordings. For instance, when questions are written in the screen, a voice asking the question is played, and for feedback on wrong answers there are also voice recordings explaining the correct answers. When the students do not understand the questions fully, they have the option of hearing them again (before answering). In order to allow blind students to confirm what they are writing (when answering questions), the game has the option of reading every character (i.e., key) that is pressed.

Non-voice 2D spatialized audio is used to help blind students navigate through the scenes. For instance, if the characters have to take the bus (in adventure mode), a bus sound is played. The intensity of these sounds vary according to the distance of the main character to the sound sources. Consequently, the sounds' intensity changes depending on whether the character approaches or moves away from the sources. More specifically, the volume of the sounds changes according to the following equation:

$$v = 1 - d/d_{max}\,,$$

where v is the volume of the sound (and varies from 0 to 1), d is the distance from the main character to the sound source and d_{max} is the maximum distance in the current scene. In addition, the sounds are played louder in the left or right channel depending on the location of the sound source relative to the main character. This creates interaural intensity differences that give the players the sensation of 2D spatialized audio, i.e., that the sound source is either to the left, right, front or back of the character.

In addition, the game contains other features specifically designed to help blind students. For instance, if a student is lost in a specific scene where the main character has to move to a certain destination, the student can press a key to make the character move automatically or another key to make the character jump to the destination. These features were included to avoid having blind students feel lost in the game and to avoid losing their interest. This way, even if they are not able to make the main character to navigate, they can enjoy the game and concentrate better in the learning mode.

D. The shortest path to the next clue

As mentioned before (section III-C), students can opt to have the main character traveling automatically to the destination (that is, the site where the next clue will be unveiled). In order to make the character move automatically, the game calculates the shortest path from the character's position to the destination. For this, the game uses the flood fill algorithm.

In order to create the foreground and background effect, each game scene consists of a map that has a few layers. The layers are divided in small areas called *tiles*, and objects and characters can be positioned in the tiles. In other words, a map is a multi-layer matrix of tiles.

Apart from those layers, each map has a special layer that was created to support the flood fill algorithm. The layer is represented by a matrix, whose entries correspond to the tiles. The flood fill algorithm fills all the entries (i.e., tiles) in this matrix with their distances to the destination tile.

To start with, the destination tile is given cost zero and all the tiles that correspond to an obstacle (like a wall, or an object) are given a maximum cost. The cost function specifies the minimum distance from the tile to the destination and the maximum cost is the total number of tiles in the map (that is, the total number of entries in the matrix). The algorithm then fills all other entries with their minimum distances to the destination. It starts filling the tiles adjacent to the destination, then the tiles adjacent to those, etc. In other words, once a tile x_i (that is not a barrier) is assigned a cost $c(x_i)$, the algorithm fills all its adjacent tiles (that have not been previously filled) with cost $c(x_i) + 1$:

$$c(x_j) = \begin{cases} 0 & \text{if } x_j \text{ is the destination} \\ \infty & \text{if } x_j \text{ is an obstacle} \\ c(x_i) + 1 & \text{otherwise} \end{cases}$$

where x_i and x_j are adjacent, and ∞ is the maximum cost, that here is represented by the number of entries in the matrix.

72	72	72	72	72	72	72	72	72	72	72	72
72	4	72	72	5	6	7	8	9	10	72	72
72	3	72	72	4	72	72	7	72	11	72	72
72	2	72	72	3	72	72	6	72	12	13	72
72	1	0	1	2	3	4	5	72	72	14	72
72	72	72	72	72	72	72	72	72	72	72	72

Fig. 3. Map with the costs assigned by the flood fill algorithm. The light gray tile with 0 cost represents the destination and the dark gray tiles represent the barriers.

Fig. 3 illustrates a map filled in this way. In order to find the shortest path from the character's location to the destination, the algorithm follows the tiles with decreasing cost.

E. Game session and log file

An important characteristic of the proposed game is the possibility of interrupting a game session and return to it later. If that happens the game will return to the same state it had right before the student interrupted the game, including the same mode, the same scene, the same characters' locations and the moment of the story.

The game also keeps track of the questions that have been posed, along with the player's answers. These data is written in a file that can be used by the teacher. This way, the teacher can verify which modules and questions are harder to the students.

F. Technical details

The game was implemented in XNA Game Studio with the RPG kit for game development. It was developed in and for Windows (it can run in any desktop or laptop with this operating system).

The game can be adapted to other math modules or even other courses by changing the questions, which are stored in XML files that also include the correct answers and feedback on the answers. There is one file for each module. New modules can be included in the game by adding new files for those modules and adding them to the games list of modules. In order to have the spoken questions and feedback on the answers, these must be recorded. While at the time being, the game must be compiled to have these changes take effect (through the generation of XNA's xnb files from the modified XML), we plan on changing the game so that it can use the XML files directly and it uses a voice synthesizer. This will make the process of adapting the game to other math modules or courses easier.

IV. RESULTS

In order to determine if the proposed game is a fun and useful tool for teaching and learning mathematics, we gave the game to visually impaired and sighted students from the 9th grade from two inclusive schools. The game was installed in the students laptops and in a few school desktops. Both teacher and students showed enthusiasm with the game. The teachers observed it could be a great tool to make the students do some math exercises and were interested in having access to the game even after the testing period. Visually impaired students were quite excited with this game because they were able to play it by themselves without the need of assistance from a sighted colleague, teacher or family member.

To test the game we followed Virvou et al. and Ketamo's methodology [4], [8]. This methodology consists of using evaluation quizzes before and after the students have access to the game, in order to determine if the grades improve significantly when the students use the game.

Before the students had access to the game, they were asked to do a math quiz with a total of nine questions from the math modules used in the game (probabilities, proportionality and functions). There were three questions from each module. After this quiz, the test period started and students were given access to the game. At the end of the testing period, which lasted for about a month, the students were given another quiz with the same structure as the first. The questions used in the quizzes were variations of the questions in the game.

In order to understand the usefulness of the game's feedback on wrong answers, we used two versions of the game during the testing period: the full version, which provides feedback whenever the student fails an answer, and another version that does not give feedback. After answering the questions, the students who used the no-feedback version, did not receive any explanation for the wrong answers nor an indication whether the answer was correct or wrong.

Unfortunately, the month chosen to test the game was a very busy month for the students, who had several tests from other subjects. As a consequence the students did not use the game as often as predicted and we only had access to the final quiz of six students. These students were divided into three groups:

- One group of two visually impaired students (one totally blind and a low vision student) who had access to the game's full version (with feedback).
- One group with one sighted student who played the game's no-feedback version.
- One group of two visually impaired and one sighted students who did not play the game.

Fig. 4 shows the results obtained by these students in each of the two quizzes. As it can be observed the group that improved the most was the group of visually impaired students who played the game's full version, that is, the version with feedback on wrong answers. The average results for the first quiz were 3.5 correct questions out of nine and 6 correct questions out of nine for the second quiz, which corresponds to an average improvement of 2.5 correct answers. Though

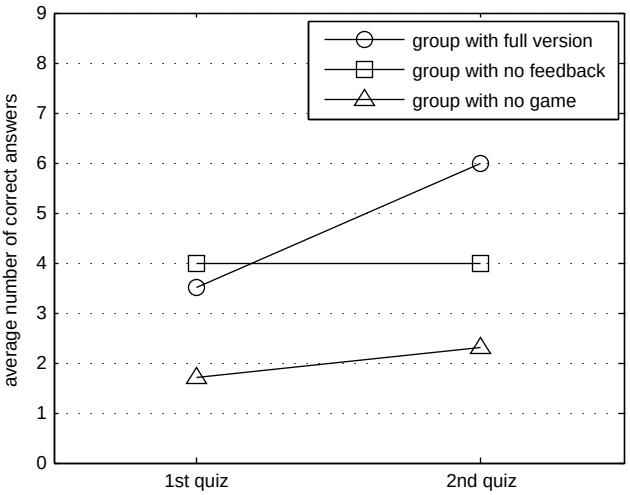

Fig. 4. Quizzes average results.

the group of students who did not play the game also showed some improvements, these were lower: average improvement of 0.6 questions. The student who played the game with no feedback, showed no improvement.

Since we collected the results of only these six students, we cannot conclude that the improvements were due to the game. Yet, the differences between the results of the students who played the game's full version and the results of the other students, suggest that the game can have a positive effect on the course's performance.

From individual interviews with the students, we know that due to the game the students practiced more math exercises than usual. For instance, the previous grades on mathematics of one of the visually impaired students (on the first term of the current year and the previous year) were negative and the student reported that he did not like mathematics, but that this game or others like this could make him enjoy mathematics better, which alone is already a very positive outcome.

In addition to the quizzes we also gave the students a few questions in which they could express their opinions about the game. It was interesting to note that visually impaired and sighted students had different opinions about the game. Visually impaired students found that the game is a fun studying tool. Students reported that this type of games can make mathematics more appealing and can be a useful tool in class. One student suggested that it would be interesting to use the game during classes to have all students playing together as a team. Students also reported that the feedback on wrong answers helped them to understand how to solve certain problems.

When asked about how the game could be improved, a student who did not like mathematics suggested to include questions from other subjects in the game or even change all the questions to another subject. This student said that the part of the game that he enjoyed the least were the question moments (that is, the learning mode). Nonetheless, the student played during learning mode and tried to answer the math

questions. This indicates that the student enjoyed both the adventure and story modes, and suggests that our proposal of including these two modes to motivate the students to play also during learning mode had the expected outcome.

Students reported that it was easy to understand how to play the game and that the audio used was sufficient to make the game interesting. Nonetheless they experienced difficulties during navigation moments as they could not understand when they crashed into a wall or car. This could make them get stuck and prevent them from reaching the destination. In response to this problem, the game now signals when the main character bumps into a wall or another obstacle, and indicates to which side the character shall turn.

The comments we received from sighted students were quite different. Since these students have access to games of several types without the restrictions blind students experience, they are used to much richer graphics. Therefore, their critics are much contrary to the compliments of teachers and visually impaired students: even though they were enthusiastic with the game they found the graphics too plain, they said that they would enjoy a 3D perspective better and in many cases they complained about the lack of violence (which, since this is an educative game, it is not an option).

V. Conclusions and Future Work

While several educational computer games have been proposed, little attention has been given to make these games accessible to all students, in particular to students with special needs. Here we proposed an educational math computer game especially designed for visually impaired students (*i.e.*, low vision and totally blind students). The goal of this game is to be a useful tool for teaching and learning mathematics, that helps the students enjoy mathematics and motivates them to study this subject. Using the game as a teaching tool, can have a positive effect on the the student-teacher relationship and also increase the student interest in mathematics. The game can be played by every student (visually impaired, sighted and even with hearing loss), contributing to the integration of special needs students with their sighted colleagues and ultimately in society.

The game has several question-answer moments, and to keep the students motivated in playing and learning, we combined these learning moments with adventure. More specifically, the game has three modes: adventure, story and learning. While this combination of modes is not very common in question-answer educational games, it allows the game to captivate the students' interest and curiosity: the students know that once they surpass the learning mode, they will reach another adventure mode. This gives them more motivation to answer the math questions. The story mode is used to glue all the moments together and make the whole game consistent.

One relevant educational characteristic of the game is its feedback system. Whenever a student fails a question, he/she receives an explanation on how to solve the problem correctly. This characteristic is important to promote learning.

The game also has another interesting motivating feature: the reward system, which aims at motivating the students to answer correctly the math questions. This feature, which can foment healthy competition among students, also stimulates the students to try to understand the feedback they receive on wrong answers in order to subsequently improve their score (in future questions).

Since the game was especially designed for visually impaired students, it has features that were included to make it accessible to these students. Sound plays an important role in the game: all the features are complemented with voiced and unvoiced audio. The questions, the feedback, the dialogs, etc., are all given by text and voice. The student can hear the characters he/she has introduced for an answer. The game uses spatialized non-voiced audio to lead the students in navigation moments (during adventure mode). In addition, several help features have been included, like the possibility of hearing a question more than once, and make the main character move automatically.

The tests run at two inclusive schools suggest that the game can lead students to improve their understanding of the material covered in the game. In addition, we had very positive feedback from both teachers and visually impaired students. Teachers commented that the content was appropriate and complimented the graphics, which could be distinguished by low vision students. Visually impaired students reported that it was easy to understand how to play the game. Totally blind students found the audio component sufficient to make the game interesting and allowing them to play by themselves. Students reported that the feedback provided on wrong answers was clear and helpful. The fact that even students who did not enjoy mathematics played through all three modes, shows that our proposal of including adventure, and story modes intercalated with learning mode motivates the students in doing math exercises.

As future work we plan to make the question-answer files editable, which will increasing the game's usability. Letting the teachers edit the questions used in the game, and using a speech synthesizer that reads those questions will not only allow using the game for other math modules, but it will also facilitate adapting the game to other subjects, such as chemistry, physics, etc. Another improvement we plan adding to the game is making it adaptable to student's capabilities. In other words, the level of the question's difficulty will adapt according to the answers' results (*i.e.*, grading) and the average time spent by the student to give an answer. This feature would make the game more useful to all levels of students (average, low and high grades).

As shown in [15], only a low percentage of students with disabilities who pursue higher education choose exact sciences and engineering courses. This may be due to the difficulties felt to learn courses such as mathematics. With this game we hope to contribute to motivate blind and low vision students to learn and to enjoy mathematics.

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