Annual Review of Cybertherapy and Telemedicine
Volume 6 Year 2008 ISSN: 1554-8716

Advanced Technologies in the Behavioral Social and Neurosciences

Editors:
Brenda K. Wiederhold, PhD, MBA, BCIA
Luciano Gamberini, PhD
Stéphane Bouchard, PhD
Giuseppe Riva, PhD, MS, MA

Interactive Media Institute
Mobile inclusion through science learning for the blind

Jaime Sánchez, Fernando Aguayo

Department of Computer Science, University of Chile

{jsanchez, faguayo}@dcc.uchile.cl

Abstract: Science learning is a complex task for school-age children, especially blind children. The purpose of this study was to develop and evaluate user perception and acceptance of AudioGene, a role-playing videogame that uses mobile technology and adaptive interfaces so that blind and sighted children can learn science and work together collaboratively, as well as the role that the program played in the integration of blind children into the school environment. A usability evaluation demonstrates that blind users felt integrated with and subjected to the same conditions as their sighted peers when gaming, which shows that there is a real possibility for integrating blind users into the school by using digital technology. The methodology and tools utilized in this study can help in that direction. Future work should identify new ways of integration and determine whether the genetic content embedded in a videogame can assist the student in learning, and as such become a powerful tool for collaborative science learning of both blind and sighted learners alike.

Introduction

The social inclusion of blind people into learning environments through the use of technology can be studied by making an analysis of four fundamentally related areas; these are the complexity of learning science, the benefits of mobile devices, the use of videogames for education, and mainstream integration.

School-level science learning can be complex for students due to the abstraction associated with the concepts involved and the impossibility of recreating similar environments. In many cases science is mostly studied theoretically because of the difficulties in correctly implementing practical activities (Johnstone, 1991). Technology plays a major role in explaining these concepts through simulations and games that can sum up processes that normally take hundreds, thousands or millions of years in a few minutes or seconds (Gibson, 2007).

Mobile devices provide the users with the possibility of using times and spaces that are not currently used for knowledge acquisition (Williams, Jones, Fleuriot, & Wood, 2005). The use of mobile devices also eliminates the barriers imposed by interacting in a small space and allows for a more fluid communication between the participants. The use of PCs in school learning generally involves the existence of a laboratory that limits the space for interaction (Salinas & Sánchez, 2006).

One of the most common student activities when using information technology is to play computer games or videogames (Mayo, 2007). Various studies show the importance of using games for education (Squire, 2003, 2005; Steinkuehler 2004), highlighting that relevant cognitive skills (Steinkuehler, 2008), such as the development of competition and concentration skills, mobility skills, language and mathematical skills, visual skills and also problem solving abilities, can be developed through the use of games (Klopfer & Yoon, 2005).

Many authors have analyzed the impact of games on problem solving skills. Some propose that games can promote higher order learning, such as increasingly meaningful dialogues among learners (McDonald & Hannafin, 2003). Other studies describe the positive effects of games on social skills (Pellegrini, Blatchford, & Kentaro, 2004).

Danesh, Inkpen, Lau, Shu, & Booth (2001) propose Geney™, a collaborative application for problem solving that teaches genetics through the use of PDAs oriented towards children. Some studies on problem solving and blind learners can be found in the development and analysis of games like AudioChile, AudioVida (Sánchez & Sáenz, 2006), and the various games mentioned...
by Eriksson & Gårdenfors (2004).

Squire (2005) poses that it is not enough to produce educational video games, but that we must adopt a new methodology based on the way of teaching in schools, proposing five aspects that must be considered: 1. Focus the contents on more transversal and less specific aspects, in a way that the students actual study and understand causes and effects and the 'why' of things. 2. Consider the heterogeneity of the group in as much as interests, abilities and capacities for learning. 3. Accommodate the schedules in a way so that a student who is interested in a subject will be able to deepen his learning. Other times outside of class can be used so that the students study concrete subjects. 4. Diversify the means of transmitting knowledge, not being limited to the classic means used by the teacher (books, movies or presentations). For example, using video games allows students to work outside of regular class schedules, motivates them and gives them another perspective on the content. 5. Orient the evaluations to have an opportunity to support learning.

School integration is a key issue in education. Some studies present and analyze the integration of learners with disabilities into the classroom, such as in the research done by Johnstone (1991). Other studies promote the key role that technology can play for the integration of users with different kinds of disabilities into the classroom (Roper, 2006). In the work done by de Freitas & Levene (2003), a complete analysis of the development of mobile devices for education is shown. Emphasis is made on the possibility of using these devices for helping users with disabilities. Particularly, they mention the benefits that can be obtained thanks to new technologies used in locating places, helping with mobility, and cognitive assistance for orientation in real environments (Rodrigues, 2006; Na, 2006). The use of technology appears to be a real alternative for people with visual disabilities in order to be able to interact and collaborate with sighted users, extending the possibilities for communication and participation in situations in which they could not traditionally be found (Chen, 2005; Dowling, Maeder & Boldes, 2005). In conjunction with this, applications have been developed to improve the strategic and analytical capacity for problem solving, which is a fundamental skill for professional, intellectual and personal development (Jaroslavsky & Narvaja, 2004).

The purpose of this study was to develop and evaluate the user’s perception and acceptance of AudioGene, a role playing videogame that uses mobile technology and adaptive interfaces so that blind and sighted children can learn science and work together collaboratively, as well as the role that the program played in the integration of blind children into the school environment.

Research questions

Blind children face different problems when interacting with others. First, they generally do not learn together with sighted peers. Their education tends to be separated from sighted children either in special schools or even in the same mainstream school, but using different learning tools. Particularly, they do not learn science and specifically biology with their sighted partners, because science learning is generally based on visual experiences. Secondly, they also do not tend to interact or socialize with sighted children because they are either isolated in special schools or integrated into regular schools but with little or no learning activities included in the curriculum that are planned and implemented to stimulate interaction and collaboration between sighted and blind learners. Finally, blind children generally do not talk, dialogue or discuss with sighted children because the former tend to socialize only with other blind children.

These issues leave us with two questions as the basis for this research: 1. Can mobile technology through gaming assist with problem solving skills in biology and help with the integration of blind children into the school environment? 2. Can mobile technology stimulate science learning in blind children as well as their integration with their sighted partners during the learning process?

Conceptual and cognitive emphasis

The way students interact during the learning process is an important and primordial aspect of learning. To learn with others and from others is indispensable for more complete learning. Students operate in a society and, most importantly, in a global society, so the emphasis on collaborative work and learning is essential (OECD, 2001). On one hand, our software emphasizes the collaborative work between blind and sighted children for solving biology problems using both graphical (for users with partial vision) and audio interfaces. On the other hand, we try to encour-
age students to face the learning process in a motivating way, testing and practicing knowledge through gaming and focusing on problem solving.

The software metaphor includes the use and learning of various concepts in genetics such as DNA, mutation, genotype, phenotype and gene. The contents have been taken from 7th to 10th grade school science textbooks that focus on the subject of genetics. Thus, a virtual world has been modeled considering each user as a key constituent who must adopt a character when gaming.

Finally, the goal of AudioGene is not just to teach biology concepts to users, but to strengthen and help them put the knowledge they have acquired in their science class into practice.

The design of AudioGene
AudioGene has been designed for mobile use through handheld devices (Pocket PC), but it can be also used with other Windows mobile devices such as cell phones, TabletPCs, UMPCs, etc. This is possible due to the use of a .NET framework that, with minimal modifications, can be implemented in other similar platforms.

AudioGene world
The game takes place in a virtual world embedded with lava, water, mountains and earth, based on school-level genetics material, and in which the user has to perform as and control a character. The game presents a story that consists of a tree of life that has certain characteristics, such as being robust, alive, wise and leafy. The user is given the scenario that the tree is dying, so it has to be replaced by another tree with the same characteristics, by using a combination of seeds that will result in a similar tree. In order to achieve the goal of the game, successfully re-placing the tree, the user’s character has to evolve into certain superior entities. He or she can evolve by learning about concepts in genetics and other knowledge. This can be done in three ways: 1. The user travels around the world freely and interacts with the characters that he/she meets; 2. The user solves a specific mission within the game; and 3. The user, in conjunction with his/her partners, solves a mission.

Interfaces
The graphic interface was designed for sighted and some legally blind users with partial vision. For all legally blind users we used an audio interface that is explained in the Audio Interface chapter. The fact that we were working with a Pocket PC device limits the design of the interface due to its reduced size. This forced us to go with a minimalist design, favoring an adequate degree of interaction without overcharging the user or the screen. To accomplish this, the use of buttons and status information was avoided. The only status information provided through the graphical interface is a figure that appears at the left top of the screen highlighting when the user acquires a certain skill (see Figure 1).

The engine developed for AudioGene allows for the handling of layers (see Figure 2) for the different objects that are drawn on the screen, and thus provides a more realistic spatial representation with a feeling for depth, so that objects can be placed in front of or in back of the other objects.

The audio interface consists of two types of sounds: 1. Icon audio is used for spatial orientation and consists of using sound clues. These sounds may correspond to the area in which the user is located. For example, when the user is over the water, a sound associated with water is played. These sounds are also utilized in order to

![Figure 1](image1.png)

**Figure 1.** Each skill is represented by a different symbol.

![Figure 2](image2.png)

**Figure 2.** (A). The handling of layers. (B). The result of applying layers can be appreciated by looking at the character situated behind or in front of the tree.
inform the blind user about the location of other users or Pocket PC controlled characters by using the audio interface explained below. 2. Speech audio corresponds to pre-recorded sentences that are used to teach the user about genetics and to ask blind users questions when they approach a Pocket PC controlled character.

With icon audio a problem emerged, in that the Pocket PC device is only capable of playing stereo audio. Efforts have been made in order to provide the user with the feeling of three-dimensional space. It is well known that headsets only allow for the use of 2 sound sources (A and B in figure 3), which makes for the possibility of 3 spatial combinations. The first two combinations correspond to only one of the sources being used (it is identified as left or right), and the other one is achieved through the use of both sources (which is intuitively identified as front) (Lumbreras & Sánchez, 1999).

This model was extended by adding a new variable (C) to the sound system. This sound is mono channel and sounds constantly together with the sound from the audio source as if it were coming from behind the user. This sound allows for three new combinations, expanding the spatial system to a total of six combinations. So the user can listen to a sound with the speaker on his right (B in figure 3A), his left (A in figure 3A) or on both (A+B in figure 3A), which means that the audio source comes from his right, left or center respectively. If the base sound is added to these sounds (C in figure 3A), then the audio source would come from the rear right of the user (B+C in figure 3A), the rear left of the user (A+C in figure 3A) or from the rear center (A+B+C in figure 3A).

When adding a rear sound for the user (C), a proposed system such as the one shown in Figure 3A is obtained.

**Database & Networks**

AudioGene allows for online multiplayer games, so the need for a centralized information system emerges. A PC with a database is required and the Pocket PCs are in charge of updating their information through the network. When the user starts a session, the Pocket PC communicates with the PC, which sends the player’s last known status back to the Pocket PC, guaranteeing the continuity of the game. This database records the state of the game, including the location of the different players, the skills they have acquired and the travel map.

Figure 3B shows the interaction between the Pocket PCs and the servers through web services. This communication takes place when starting and ending a game session, allowing the user to get the information stored the last time he/she played and then to store the information again in order to access the new state of the game for the next session. The use of web services allows for the use of Pocket PC devices behind a firewall to communicate with the server.

![Diagram](image_url)

**Figure 3.** (A) Audio system proposed for AudioGene. (B) A logic-based diagram of interaction
Methodology

Participants
The sample consisted of five legally blind children and three sighted children. They were distributed in two groups of four children each. Each of these groups contained one blind user and three sighted users or users with visual disabilities. Two out of five blind children were totally blind and three had residual vision (see Figure 4C). Four children attended the “La Maisonette” school that runs a school integration program (mainstreaming) and four attended the “Escuela de Ciegos Santa Lucia”, both of which are located in Santiago de Chile (see Figure 4A-B). Two facilitators participated in the study, one from the team that developed AudioGene and a special education teacher who specializes in visual disabilities.

Instruments
In order to gather data and information about the blind learners’ opinions, perceptions, and their acceptance of the software and the experience of gaming with their sighted partners, an open-answer questionnaire was administered. Questions such as, “How do you play with your partners?”, “What do you think about AudioGene?”, “Did you like to play AudioGene with your friend?”, “Do you like science?”, “What do you think about this new way of learning?”, “Would you like to play more games like AudioGene?”, and “Would you play AudioGene again?”, were asked.

The purpose of these open-ended questions was to obtain opinions, perceptions and the degree of the software’s acceptance from the users that played the game and who interacted fully with their partners. The question, “How do you play with your partners?” was intended to identify the real way in which blind children played in conjunction with their sighted partner, coming to understand, as such, the novelty that a game like AudioGene might represent for them. The rest of questions focused on getting information about the software, the experience with the software and the way that it contributes to school integration and learning.

Procedure
The following are the stages used in order to administer the survey: 1. Introduction to the game. The user receives explanations about the purpose of the game and how to use the Pocket PC device; 2. Interaction with AudioGene. Users have to navigate the virtual environment and collaborate with their team peers. The two groups played AudioGene during four 30-minute sessions during a one-month period of time, and were all made to complete the same mission collaboratively between the 4 team members; 3. Administration of the questionnaire. When the children finished the four sessions of interaction with AudioGene, they were given the questionnaire in order to gather data and information about their opinions, perceptions, and acceptance of the software and the experience of gaming with their blind or sighted partners. The users answered the questions in the questionnaire, which was administered verbally by the facilitators.

Results
The results having to do with the users’ perceptions of playing and interacting with AudioGene were analyzed. None of the children that participated had ever interacted with a mobile Pocket PC device before. They only knew about them through the media. The most similar device with which they were well familiarized and that they handled daily was a cell phone.

<table>
<thead>
<tr>
<th>#</th>
<th>Age</th>
<th>Gender</th>
<th>Diagnostic Ophthalmologic</th>
<th>Degree of Vision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>13</td>
<td>M</td>
<td>Bilateral Optic atrophy</td>
<td>Residual Vision</td>
</tr>
<tr>
<td>2</td>
<td>14</td>
<td>F</td>
<td>Retinopathy of Prematurity</td>
<td>Totally Blind</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>M</td>
<td>Microphthalmus</td>
<td>Residual Vision</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>M</td>
<td>Aniridia, Glaucoma, Cataract</td>
<td>Totally Blind</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>F</td>
<td>Hypoplasia of Optic Nerve, Iris Coloboma, Microphthalmos</td>
<td>Totally Blind</td>
</tr>
</tbody>
</table>

Figure 4. (A) Children playing AudioGene. (B) “La Maisonette” school students “Escuela de Ciegos Santa Lucia” students. Children interacted in places other than the formal classroom. (C) Ophthalmologic characteristics and diagnosis of participants with visual disabilities.
How do you play with your classmates? One of the answers to this question was “we play soccer matches”. To do this, they put the ball inside plastic bags in order to hear when the ball is moving. Thanks to this sound children with visual disabilities are able to follow the movements of the ball and play without any problems. Also, most of the children reported that they do not play any games in common with both sighted and blind children playing together.

One of the children that participated and who knew of AudioLink (Sánchez & Elias, 2007), a desktop game for the orientation, mobility and science learning of blind children through virtual environments, said, “… sound based computer games like Link is a game that includes sounds and teaches us how to orient ourselves in an easy and entertaining way.”

One totally blind girl that participated in the study did not have any sighted friends. She only interacted with blind children, so she was very excited about the idea of interacting, playing and meeting sighted children. Some of her partners that have partial vision said, “… it was very interesting to play with sighted children.”

What do you think about AudioGene? All of them found that AudioGene was entertaining and motivating. They focused mainly on the possibility of accomplishing tasks in conjunction with their partners. Sighted children liked and enjoyed playing with their blind partners. For the blind children, the fact of being able to work in conjunction with their sighted partners through the use of technology was a very good experience, and they liked to participate and work as a team with them.

Did you like to play with your friends? Both teams agreed that to play all together was a very good experience. They could participate and achieve the proposed objective collaboratively as a team, as well as pursue individual tasks.

Do you like science? All learners liked science courses. They found them entertaining and interesting, but not all of them found science easy. Most of them considered it to be a difficult subject. A blind girl said, “Yes, I like it and find it interesting, but it is difficult for me to understand and learn science.” Another one said, “… I like it more when they teach you about space and ani-

mal subjects, by asking questions. Some topics are very complicated and are more difficult to understand than others.” Some of the children said that when they can not understand the contents, they do not like it anymore, “… I like it when we learn about animals and that kind of subject, when we do not understand something we don’t like it.” AudioGene made them understand a difficult subject, such as genetics, in an entertaining and different way.

What do you think about this new way of learning? Children found this way of learning more entertaining than reading books, and also more motivating. A blind girl even added, “I am going to propose it to my teacher…” meaning that she will suggest that her teacher adopt this kind of teaching method. The rest of her partners supported this idea in saying, “Yes that would be very interesting.”

Would you like to have more games like AudioGene? All children answered that they would like to have more games like this one. They established that one of the advantages is that they can interact, play and learn all together. A blind girl stated, “It is good, because all of us can be there and is fun to play with it. Especially in the way that it teaches that all the people in the world are different; there is no single person that is equal to another. Some can cross over lava, others can cross over water, but the ones that can cross over lava can not cross over water.” The idea being transmitted here has to do with the metaphor used in the game, which teaches that all people are different and have different skills and virtues. One of the children supported the idea of creating and have more integrated games, and concluded, “… we can not live in a world where all people are sighted, or in a discriminating world where the sighted are separated from blind people.”

Blind users not only felt integrated with their sighted partners, but they enjoyed this kind of integration and the feeling of not being limited in their interaction with sighted people as well.

Would you play AudioGene again? All the children answered yes to this question. This motivates us to continue working with this tool in the future and to test its capacity for the development of learning skills. A blind girl also added, “The interesting thing about games is not only playing with sounds, but being able to touch and feel the
game as well.”

**Conclusion**

The purpose of this study was to develop and evaluate the users’ perceptions and acceptance of the software, and the role that these played in the integration of AudioGene into the school environment. AudioGene is a role-playing, mobile videogame used to learn science and for collaborative work between sighted and blind users.

Kloper and Yoon (Kloper & Yoon, 2005) said that games produce a high level of commitment and motivation in learners, and that these attributes can be useful for improving learning activities. In this study, blind users accepted and were highly motivated to use AudioGene. They felt that they were in the same condition as their sighted partners. This is never the case when using technology in general. Also, all the children who participated in the experience, blind and sighted alike, recognized that learning science is interesting, but that sometimes it is difficult to follow without losing their motivation in the end.

AudioGene proposes a new way for learning science, and specifically genetics. The main achievement of this game is that children take an active and constructive role, learning in an interactive and motivating way. The children enjoyed this new way of learning; they felt motivated and participated in the tasks involved actively and in collaboration with each other during the course of the game.

Children had to organize themselves in order to define a strategy and achieve the proposed task. All of them did this task well and achieved the end goal. This is an important result in terms of the utility of the problem solving methodology. AudioGene helped to integrate blind and sighted users, stimulating science learning for legally blind users. This game has embedded problem solving tasks for science learning that can be used anytime, anywhere, and through the participation of blind and sighted users under the same conditions. Also, the game helped to produce a work environment in which differences were forgotten and children interacted freely with each other. They shared ideas to solve the proposed problem, and knowledge was constructed between all four members of each team.

It is widely known that it is important to generate spaces in which children feel motivated to learn and construct knowledge. In this direction, new technologies can help a great deal, especially from the perspective of communication and collaborative work. This new way of learning has to be accessible for all users without leaving anyone out. A tool like AudioGene opens the possibility of constructing spaces where blind and sighted children can work together and achieve common goals.

The experience presented by de Freitas & Levene (2003) is complemented by the results presented here, because we show that mobile devices can not only help legally blind users pursue their learning tasks, but their integration with a tool such as AudioGene as well, which represents a powerful tool for social integration.

What Pellegrini et al., (2004) mentioned is corroborated in this study as well, because the use of AudioGene allows blind children to be socially integrated with their sighted partners, to participate actively in society, to be interested in learning science material and to use learning methods like gaming with digital and mobile devices. Judging from the children’s comments, we highlight the fact that the game allowed legally blind children to work fully integrated with the sighted children, and to feel as part of the whole group. This is very important in order to achieve an improved and more complete learning process, not only of the subject matter, but skills for working collaboratively as a team as well.

The AudioGene game focuses on the current and very important issue of the integration of children with visual disabilities and their sighted partners in school, as the former are considered as a segregated population. It also uses mobile technologies and modern methods for school-level science learning. The fact that it is a mobile application allows the children to go outside their classrooms and develop naturally in other environments, with the assistance of technology. The use of non-formal learning spaces like museums, zoos and squares for learning by a variety of users is a new window of opportunity opened by applications like AudioGene.

Future studies should identify the degree to which school integration can be attained by working with tools like AudioGene in more depth. In this paper, qualitative, preliminary, and exploratory data was presented that has served as a base in order to formulate a new, more long-term
project with an intervention in nine integrated schools, from which more complete quantitative and qualitative data is expected to be obtained.

In addition, interventions with AudioGene in environments outside the classroom, like a museum, could be a challenging task in the search for innovative ways to learn science.

Acknowledgements

This report was partially funded by Fondecyt, Project 1060797 and PBCT-CONICYT, Project CIE-05.

References


