

Design of a prototype for students with hearing limitations

Diseño de un prototipo para estudiantes con limitaciones auditivas

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Abstract

In the field of educational inclusion, the creation of accessible technologies has become essential to ensure an equitable learning experience for all students. Specifically, college students with hearing impairments face unique challenges in the academic environment, where effective communication and access to information are crucial. This study focuses on the design and implementation of a technological prototype specially designed to meet the needs of this group of students from the Pánuco Higher Technological Institute. The "Top-Down" methodology was used, which seeks to solve minor problems and then address the main problem. As a result, a functional prototype is presented that has been tested on students, who provided positive feedback regarding the improvement of their listening ability. It is concluded that technology can enhance the inclusion of students with disabilities through tools that support their learning process.

Keywords: amplifier; hearing impairment; hearing problems; students; university students

Resumen

En el ámbito de la inclusión educativa, la creación de tecnologías accesibles se ha vuelto esencial para asegurar una experiencia de aprendizaje equitativa para los estudiantes. Específicamente los estudiantes universitarios con discapacidad auditiva enfrentan desafíos únicos en el entorno académico, donde la comunicación efectiva y el acceso a la información son cruciales. Este estudio se concentra en el diseño e implementación de un prototipo tecnológico especialmente diseñado para atender las necesidades de este grupo de estudiantes del Instituto Tecnológico Superior de Pánuco. Se empleó la metodología "Top-Down", que busca resolver problemas menores para luego abordar el problema principal. Como resultado, se presenta un prototipo funcional que ha sido probado en alumnos, quienes brindaron retroalimentación positiva respecto a la mejora de su capacidad auditiva. Se concluye que la tecnología puede potenciar la inclusión de estudiantes con discapacidad mediante herramientas que apoyen su proceso de aprendizaje.

Palabras clave: amplificador; discapacidad auditiva; problemas auditivos; estudiantes; universitarios

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INTRODUCTION

In the broad educational landscape, each student undertakes a singular journey, marked by challenges and opportunities, where the inclusion stands as a fundamental principle that aims to ensure everyone, regardless of their capacities or limitations, has equal access to a high-quality education (Cruz et al., 2023). Regardless of the progress in terms of inclusion, significant challenges remain to specific vulnerable groups, like university students with a hearing impairment, who can face additional obstacles that make their academic experience harder and their full incorporation into academic life (Valdiverso, 2023).

According to the World Health Organization (WHO), hearing impairment is defined as a decrease of the hearing capacity with a threshold above 25 decibels. Statistics indicate that approximately 5% of the world's population, equal to 466 million people, suffers from some kind of hearing impairment, including 34 million boys and girls. It is estimated that, for 2050, 2500 million people will have some degree of hearing loss and at least 700 million will need rehabilitation (WHO, 2023).

In Mexico, about 2.3 million of people have a hearing impairment, being over the 50% people older than 60 years old, around the 34% between 30 and 59 years old, and approximately the 2% are children (INEGI, 2020). The Convention on the Rights of Persons with Disabilities emphasizes, in their general principles, the importance of an effective and full inclusion and participation in all the spheres of life. Considering that education is an essential function,

adhering to these principles is crucial when planning formative activities. Therefore, educational institutions must implement strategies to help students overcome the difficulties they could encounter regarding their environment. (ONU, 2006).

According to Márquez & Cueva (2020), the growing acknowledgment of social inequality and the progressive reinforcement of the human rights, particularly in terms of the right to education, equal opportunities, and diversity, has driven the development and uptake of the concept of inclusion in a contemporary society. Inclusive education is defined as a pedagogical approach that values diversity as an enriching element to the educational process, thus, beneficial to human development (Maya et al., 2023). According to UNESCO, an inclusive perspective in education involves considering the individual requirements of students, ensuring their participation and success as a group. This approach recognizes the individuality of each person in terms of characteristics, interests, abilities and learning needs, in addition it pays particular attention to those students in risk of marginalization, exclusion or poor performance. (Arévalo & Mendoza, 2023).

The Organization of Ibero-American States for Education, Science and Culture, conceives the inclusion in education as a process destined to ensure the right of all the students to get a high-quality education, with particular emphasis in those in situations of higher vulnerability (Martins & Gordillo,

2022). This principle is sustained by the Article 3 of The Political Constitution of the United Mexican States, the same that establishes the universal right to education. However, plenty educational institutions still lack inclusive classrooms, technology, or infrastructure, which perpetuates the inequality in opportunities (GOBIERNO, 2021).

Consequently, it is essential that inclusive values are deeply ingrained in the tissue of educational institutions. Nevertheless, despite the scientific advances, there exists a considerable gap between the needs of the environment and the needs of academic administration (Reimers, 2022). In that sense, students with hearing impairment face particular challenges to interact with people and their surroundings, which can lead to discriminatory situations (Montoya, 2021)

Hearing loss impacts the capacity of a person to perceive sounds at different levels, which may complicate speech comprehension and oral communication. In the university environment, where interactions are based on real-time oral communication, students with hearing impairment may face significative challenges to fully participate in the educative process (Peñaloza et al., 2023).

University, as an institution dedicated to intellectual development and the pursuit of knowledge, should be friendly and inclusive to all students, independently from their abilities or limitations. However, for those with hearing impairment, reality can be highly different (Vélez & Maijarrés, 2020). The

lack of access to auditory information and the limitations in communication can turn the classroom into a hostile environment, where active participation and academic commitment are obstructed by linguistic and technological barriers (Espitia & Murcia, 2023).

Technology has been a crucial ally in the search for solutions for people with disabilities, offering tools and resources that ease communication and access to information (Toala et. al., 2023). Nowadays, there are technological tools designed for inclusive education in existence, which make the education accessible to people with hearing impairment. These tools can improve communication between teachers and students under these circumstances, some of which include:

- **"Breaking Sound Barriers"**: A mobile application and website which seeks to encourage the inclusion of young people with hearing impairment in educational environments, offering real-time transcriptions of the lectures given by teachers. Furthermore, it allows students to take notes, ask questions, participate in discussion forums, and more (Telefónica, 2018).
- **"Google Meet"**: Allows subtitles in the course of calls, facilitating comprehension during video conferences (Google, 2023).
- **"Amazon Transcribe"**: This automatic speech recognition (ASR) service simplifies the conversion of voice into text in apps and it is also used to subtitle.

It allows tagging people during conversations or meetings, making it easier for students with hearing impairment to identify them (Amazon, 2023).

- **"Google Live Transcribe"**: A Google project that transcribes speech in real-time on Android devices, in over 70 languages, and notifies about sounds in the user's surroundings (Google, 2019).

- **"Petralex"**: A mobile app that is adjusted automatically to the user's hearing level, taking advantage of the smartphones technology to provide a maximum amplification of sound, similar to a conventional hearing aid (Petralex, 2023).

- **"Háblalo"**: A tool designed to help people with hearing impairment to communicate, where the user writes a text message while the app reproduces it, allowing the other person to hear and answer, with the app transcribing the message back to the user with hearing impairment (Techonologies, 2021).

- **"Apple Accessibility Hearing"**: Includes a set of tools for subtitles, noise cancellation in loud environments, video communication in high definition for sign language, and RTT (Real-Time Text), a technology that enables an instant transmission of messages as they are typed. Additionally, it offers support for braille displays in all devices (Apple, 2023).

This research describes the progress of a technological prototype, specifically intended for university students with hearing impairment. This

development has an outstanding importance on both the educational and the social fields since its implementation can mean a remarkable contribution to promoting educational inclusion and equality of opportunities in the university setting. When promoting accessible tools and resources, this development aims to build a more favorable environment for the learning and the academic development of this group of students.

METHODS, TECHNIQUES, AND INSTRUMENTS

A "Top-Down" hardware design methodology was implemented, which is a hierarchical and structured approach used in complex hardware systems development. This method starts with a vision of the global system and progressively decomposes its components until it reaches more specific details. By doing so, it allows designers to obtain a complete and coherent comprehension of the system from the beginning, which makes easier the recognition of requirements and the amplification of the system's architecture.

The "Top-Down" approach offers a mindset oriented to, first, solve minor issues, and then, to integrate them to address the main problem. Based on this premise, the following sequence was established for the prototype's development:

1. A systematic analysis of literature was conducted with the aim of gathering, evaluating, and synthesizing existing research, along with

prototypes that deal with problems similar to those intended to be solved.

2. Development stages

- **Microphone:** This stage consists of an electronic system that includes an integrated microphone, connected to an audio pre-amplification system. Its purpose is to filter and enhance the speaker's voice to send it through an audio amplifier.

- **Audio Amplifier:** This stage is characterized by increasing the flow, therefore, the power of the electric signal coming from the pre-amplifier. Moreover, it enables the capacity to connect it to speakers to reproduce the analyzed audio.

- **Bluetooth Multipoint Audio transmitter and receiver:** This device allows the reception of the audio from the amplifier system and sends it via Bluetooth to compatible wireless earphones, allowing the receiver (a person with hearing impairment) to listen in a more customized way what the speaker says.

- **Bluetooth wireless headphones:** These devices receive the audio from the Bluetooth transmitter and receiver, allowing the receiver (a person with hearing impairment) to listen in a more customized way what the speaker says.

- **Smartphone or electronic tablet App:** Through these electronic devices, the signal is received from an IP camera integrated on an application developed in Android Studio. Furthermore, a Google service has been incorporated named “Live Transcribe +”

(speech-to-text translator) with the purpose of making possible to visualize in a text what the speaker is discussing.

In figure 1 are presented the stages for the development of the complete prototype, providing a general vision of the operating process. This process implies capturing the voice through a microphone, whose audio signal is then increased by an amplifier previously developed in a board. Subsequently, this signal is transmitted through a Bluetooth multipoint audio transmitter/receiver module and directed towards the headphones, responsible for converting the amplified electric energy into acoustic energy.



Figure 1. *Prototype operation model.*

RESULTS AND DISCUSSION

With the objective of confirming the correct operation of the hearing prototype, the following procedure was used:

An audio pre-amplifier was used to improve the signal from the microphone. This electronic device is responsible for filtering the signal to ensure it reaches the audio amplification stage in the best condition. The schematics and the audio pre-amplifier are presented in figure 2 and 3, respectively.

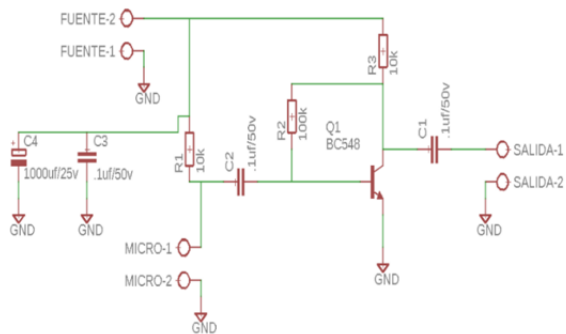


Figure 2. Pre-amplification electronic diagram.

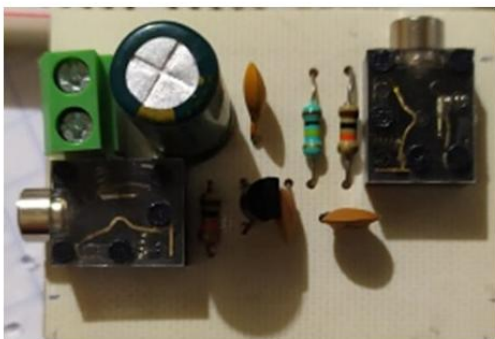


Figure 3. Audio pre-amplification circuit.

The amplifier circuit was initially evaluated on a protoboard and subsequently crafted on a phenolic board. The circuit, shown in figure 4, achieves successfully the adjusting of the transmitted audio signal from a microphone. Also, the speakers were connected to the circuit, allowing the reproduction of the professor's voice located at the front of the class.

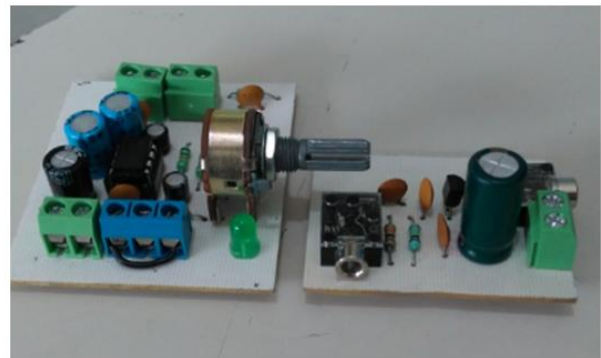


Figure 4. Finished amplifier circuit.

The mobile app developed with Android Studio provides the user with the capacity to transcribe the audio signal (Figure 5). On top of this feature, a video cam was added in the classroom to let the student visualize the images from the board from different angles and follow up the academic topic covered. The application consists of two screens, deployed to meet the user's needs. By pressing the microphone icon, the user can access a screen where an audio signal can be sent for transcription. On the other hand, the video icon provides the option to connect an IP camera to see the classroom's board.

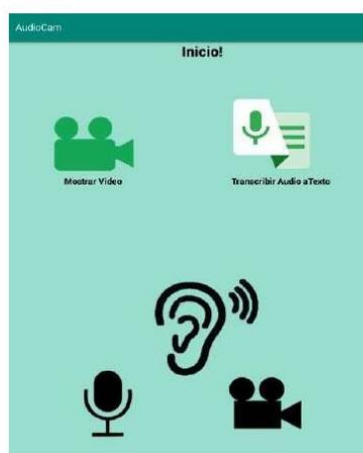


Figure 5. Mobile app developed on Android Studio.

To evaluate the effectiveness of the prototype, some tests were conducted with the help of an electronic engineering student with hearing impairment. The student said that “his auditory capacity improved significantly.” Currently, the prototype is on a testing phase, since it is fundamental to consider different parameters based on the communication needs of the students with hearing impairments, as well as the opinion of experts like audiologists and otorhinolaryngologists. For the next stage, it is planned to evaluate the prototype with 15 students from the Instituto Tecnológico Superior de Pánuco who have hearing impairment: 9 women and 6 men.

Recent studies have explored the use of advanced hearing aid technology in educational environments. A study conducted by Smith et al. (2019) researched the impact of advanced headphones in university students with hearing loss, showing a significant improvement in speech understanding in noisy environments.

On the other hand, García et al. (2021) examined how assisted listening devices that are connected to Wi-Fi networks improved the quality of sound in the classroom, providing a better understanding of the lessons and decreasing listening fatigue.

Technology has also allowed the development of more sophisticated headphone prototypes, like the smart hearing aid designed by Kim et al. (2020), which uses artificial intelligence to automatically tune the sound levels depending on the environment and the hearing preferences of the user. Additionally, the incorporation of augmented reality technologies with headphones, as researched by Li et al. (2022), provides an immersive and educational experience.

The impact of hearing prototypes on the academic performance of students has also been studied. Johnson et al. (2021) found that the use of assisted listening devices led to significant improvements in grades and class participation of the university students with hearing impairment, emphasizing the importance of auditory information accessibility to academic success.

CONCLUSIONS

The reviewed analysis highlights the importance and the potential of hearing prototypes to improve the educational experience of university students with hearing impairment. The implementation of advanced technology, such as artificial intelligence and augmented reality, opens up new opportunities for the development of devices that not only improve

hearing, but also adapt to the individual requirements of the students.

Technology offers a significant path to enhance the inclusion of students with impairment, to provide tools that support their learning process. The implementation of these tools in classrooms is crucial, since it allows the incorporation of digital resources that enrich the educational environment and promote an inclusive learning experience. This approach considers the student's diversity in the institution and helps to change the learning environment, resulting in better academic performance.

The presented prototype emerges as an effective option for the educational environment, working as an enhancing classroom communication tool. This technological assistance not only enhances the teaching-learning process, but widens the opportunities for people with hearing impairment, by easing clear and effective communication. This helps students to fully participate in academic activities, improving their integration and academic success.

However, as the research and development of this field continues, it is essential that educational institutions consider the implementation of these technologies. These are not only beneficial for students with impairments but also promote a diversity and inclusion culture inside the educational institution.

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