Dedoscopio Project: Making Astronomy Accessible to Blind and Visually Impaired (BVI) Communities Across Chile

Column

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Chile currently hosts more than 50 percent of the world's astronomical infrastructure and is internationally recognised for its pristine skies. Motivated by this access to the field, the Chilean astronomical outreach community over the past 10 years has brought the complex language of astrophysics closer to the public. However, Chilean people affected by blindness and visual impairments (BVI) are still largely marginalised from the inherent visual beauty of the cosmos. Science outreach channels, in general, do not account for the needs of people with disabilities. Expanding the frontiers of astronomy outreach and, more importantly, bringing visibility of the BVI community into society at large, resulted in the creation of Dedoscopio. We, the Dedoscopio team, have developed outreach activities for people with visual disabilities, using tactile materials as a medium to represent astronomical concepts and phenomena. The materials are handmade by the team using accessible, everyday and low-cost materials. While developing our work, we found a void in equal access to both scientific and cultural activities. In this article, we explain the materials Dedoscopio has produced and the different activities we have implemented to increase the number of scientific-cultural activities for people who are BVI within Chile.

Introduction

Chile has a very important role in the development of astronomy due to the excellent observing conditions in its northern region. The country hosts 55,6 percent *(Unda-Sanzana, 2020)* of the observatories around the world. This makes astronomy a popular subject within the country, in addition to the intrinsic attraction that people have towards this science.

Outreach activities have increased in Chile in the past 10 years. Public and private entities have started to invest in science outreach to encourage interest in astronomy and to stimulate scientific literacy. However, there is a particular segment of the population who has great difficulty accessing these activities: blind and visually impaired (BVI) people.

According to the Chilean Society of Ophthalmology (SOCHOF) *(Lopéz, 2018)* about 850,000 people in Chile live with a visual impairment, 80,000 of whom have blindness.

Inclusion as a concept proclaims that all people, despite their disabilities, have the tools to develop themselves within society, but this does not ensure that inclusion takes place in all areas of society.

For such a large population, we found that there were very few resources available, particularly in astronomy, during our three years doing outreach activities through the Faculty of Mathematics and Physics at the University of Concepción. After completing our degrees we decided to focus on astronomy outreach to BVI communities to reduce this gap in access. Thus, at the beginning of 2018 we began to give astronomy talks around Chile focused on visually impaired audiences as Dedoscopio. We aim to create a more inclusive society through these multisensory astronomical talks and in this article we show how we have reduced this inequality gap to science for people with disabilities.

Dedoscopio Resources: Talks Complemented by Tactile Materials

Our materials go through testing and development before reaching their target audiences.

First we decide the subject we will talk about according to the latest news in astronomy at a global level, such as the landing of InSight in Mars or the first Black Hole picture, or commemorations such as the Asteroid Day or the annual theme of the Day of Astronomy in Chile.

Then, we define 4 to 6 associated multisensory experiences and models, which we develop, test and improve upon. When the talk is ready, we then schedule free visits to BVI groups in Chile in exchange for their feedback. The whole process takes between 2 to 3 months until we reach the target groups.

Over three years we have created five tactile astronomy talks with the following topics:

Electromagnetic Spectrum: Audiences learn what an electromagnetic wave is and its importance within astronomy. In this presentation we show the electromagnetic spectrum, where each part of the spectrum is represented with wool, thread, and noodles of different thicknesses and textures. As an example we represent the multiwavelength Milky Way picture, with every part of its spectrum textured in a specific way (Figure 1).

Asteroids: Audiences learn about asteroids, meteors and 'shooting stars'. Here we present a not-to-scale representation of the Solar System to highlight the asteroid belt and Kupier belt, which are depicted using small circular noodles. The planets are represented through balls of different sizes complemented with an orbit in wood and the Sun is represented by a ball covered with cotton.

Mars: Audiences learn about the exploration of Mars and the use of robots to obtain information. We share a Mars model made of a polystyrene sphere. We have carved the Martian mountains and canyons into the model and marked the polar ice caps with salt. Also we show Deimos and Phobos to-scale as non-uniform moons.

Black Holes: Audiences learn about the formation, growth and shape of a black hole (BH). We share a representation of an Active Galactic Nuclei (AGN) using a spiral cardboard base. We glued synthetic cotton (gas) to the base to form a torus and sand (dust) closer to the centre of the base to form the accretion disk. We placed a stick through the centre of the base to form 'jets' and so we could spin the model to recreate the movement of the AGN (Figure 1). To represent the effect of the BH on an object we used magnets that would feel as the attraction around the event horizon.

Solar Eclipse: Audiences learn the cause of solar eclipses, how often they occur and the precautions to take when observing one. In this demonstration, we make Earth-Moon scale models with small plastic spheres and a wool thread to show their mutual distance to-scale, the Sun is represented with arms outstretched held a meter apart, explaining that this would be the diameter of it.

The models in these presentations are handmade with accessible materials such as cotton, lentils, paperboard, silicone, sugar, and wooden sticks (Figure 1).

Different materials stimulate the sense of touch differently *(Salinas, 2013)*, so people associate different textures to different concepts and physical processes. We are careful of this phenomenon as we create our models. For example, to show the Milky Way in different wavelengths we print images of the galaxy in each part of the spectrum and paste a different material onto each image: EVA foam to represent radio waves, sugar for UV band to show the young, hot stars, small circular pasta to represent X-ray sources, etc. (Figure 1) We also account for people with partial blindness when we develop these models. We make sure the material and the textures have contrasting colours, i.e. we place dark soil onto white cotton or yellowish wood onto black paperboard. Additionally, we use labels in Braille and macro-type in contrasting colours so more people can easily read them.

Testing Dedoscopio Resources

All our tactile materials are tested before they are presented at a talk. The social sciences department of University of Concepción hosts ARTIUC[1], a programme for BVI students at the university. ARTIUC members test the materials and give us feedback to improve them.

During a testing session we usually meet with 4 to 5 students, give a short background talk on the astronomy topic, and then show our materials and explain their meaning. The students test the shape, steadiness and comfort of the material with their hands. Sometimes they understand the meaning of the materials, but other times they recommend changes to the material or suggest a different way to explain. In one particular instance, when we created the not-to-scale representation of the Solar System to highlight the asteroid belts, we only used cotton to define the Sun. Our test group suggested that, as the cotton may have a confusing shape, it is not a good representation of the Sun as a sphere. They recommended that it would better to cover a sphere with cotton instead.

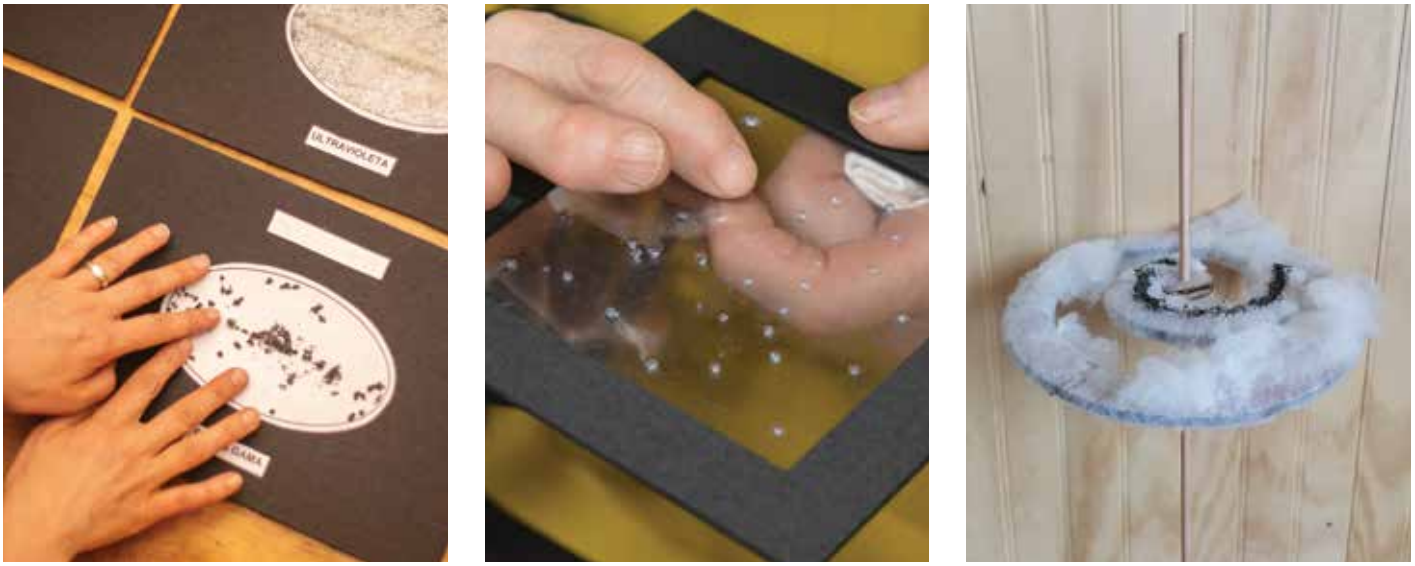

Figure 1. *Examples of handmade materials for Dedoscopio.* ***a)*** *(left) A multi-wavelength images of the Milky Way, where different parts of the electromagnetic spectrum are represented by different textures (sand for gamma-ray, sugar for UV, pasta for X-ray, and confetti for IR).* ***b)*** *(centre) A tactile sky field where the 3D dots represent asteroids in the field. The other side of the card is the same field an hour later, so a user can use both hands to search for dots and understand how the field has shifted.* ***c)*** *(right) A representation of an Active Galactic Nuclei using cotton for the torus, sand for the accretion disk and a wood stick for the jets. Credit: Dedoscopio Project*

We also receive additional feedback from specialist educators, differential educators, and social workers at ARTIUC. The group loan us their machines to create Braille and macro-type labels.

Outreach Actions in Schools around Chile: Implementation and Assessment

Typically, the Chilean BVI communities meet in small groups of 12 to 20 people in their towns. Their ages range from 20 to 63 years old. Children are immersed into the school system, so it is difficult to reach them through these communities.

On February 2010 a law was enacted which promotes development at social aspects (e.g. education, work, health, etc.) of people with disabilities in Chile. Although it is a law, there are no guarantees that it will be fulfilled successfully. In our activities we have found that, on average, 15 percent of the attendees know Braille. With children attending schools of their parents' choice there is no guarantee that they will have a teacher who knows Braille.

We started our tactile talks in 2018 in our home region of Biobío. Chile is a long and narrow country divided into 16 administrative regions. The first talk was in Cañete, Biobío Region, located at the end of the central zone, and then we visited 6 cities in the same region: Mulchén, Los Ángeles, Concepción, Penco, San Pedro de la Paz, and Lebu. We later expanded throughout Chile (Figure 2).

Over the past three years, we have visited 263 people, mainly adults, through 15 groups in seven regions in our country. In addition to the Biobío Region, we have been to the towns and cities of Freire, Lautaro, Loncoche, Padre Las Casas, Pucón, Teodoro Schmidt (Araucanía Region); Puerto Aysén (Aysén Region); La Serena (Coquimbo Region); Panguipulli (Los Ríos Region); Santiago (Metropolitana Region); and Rancagua (O'Higgins Region).

To understand the impact of our talks, we administered brief pre- and post-event tests. The questions were directly related to the main concepts of the delivered talk and highlighted by the tactile materials.

The test was performed on participants, who agreed to freely answer the pre- and post-tests, where we also included data on their level of visual impairment, age, gender, level of education and valorisation questions related to the talks.

Regarding the content of the pre-test, the central question was:

- *What do you know about astronomy?*

This question is open, i.e., the participants freely answered what they knew about astronomy or the first concepts that they can remember.

For the post-test, the central pre-test question was repeated, adding further questions about the concepts and tactile materials addressed during the talk, both as closed or open type questions.

According to the tactile representation:

- *How many parts does a black hole have?*
- *What is the light path?*

According to the content of the talk:

- *Do black holes work like a vacuum cleaner?*
- *What is a Supernova?*

The tests were carried out on the same day as the talk, either a few minutes before starting (pre) and at the end (post).

From the participants who took the test 41,1 percent of them were high school students, 30 percent university undergraduates, 11,8 percent university graduates and 17,1 percent had only finished primary school.

Through these tests, we found that more than half of the participants understood the astronomical and physical phenomena through the materials presented and that they had a strong interest in participating in similar activities in the future.

The answers about their previous knowledge focused on what they had learnt during their schooling period, such as concepts of the Solar System, the Moon, and the Milky Way, but they recognised that they never really understood them. The answers about their gained knowledge revealed that only 33 percent of them

Figure 2. *The red pins in this representation of Chile, indicate where the Dedoscopio team has visited across Chile since 2018. The team has visited 21 groups and cities across seven regions. The team has visited the following groups: (from top, or north, to bottom, or south): the school Colegio Luis Braille and groups Acaluces and Ulivis in La Serena, Coquimbo Region; the school Colegio Santa Lucía in Santiago, Metropolitana Region; the school Juan Tachoire Moena in Rancagua, O'Higgins Region; the groups Acivic, ARTIUC, Grupo Renacer, Luceritos, and Victor Jara, the school Escuela Juan Madrid Azolas, the rehabilitation center Amilivi, and municipalities of Cañete and Mulchén in the Biobío Region; the cities Lautaro, Loncoche, Padre Las Casas, and Pucón, and the towns Freire and Teodoro Schmidt in the Araucanía Region; the city of Panguipulli in the Los Ríos Region; and the group Visión Futuro in the Puerto Aysén, Aysén Region. Credit: Dedoscopio Project*

Figure 3. a) *(left) An example of the talk using tactile materials, kids from Colegio Luis Braille speak with a Dedoscopio team member while interacting with tactile material to understand black holes.* ***b)*** *(centre) A Chilean Sign Language interpreter signs during the talk Eclipse Curioso: Una Actividad Inclusiva (Intriguing Eclipse: An Inclusive Activity).* ***c)*** *(right) During an astronomical congress, sighted astronomers wearing blindfolds participate in a tactile talk. Credit: Dedoscopio Project*

understood the new concepts delivered during the talk.

This small increase may have three main causes:

1. Our talks are the first time they attended a science talk, so they were not used to receiving new, unusual information and adding it to their knowledge base;
2. The education level affected how they understood new concepts;
3. The structure of the talks was not well designed.

Since both the talks and materials were tested with ARTIUC, we therefore believe that the small change in knowledge acquisition is a combination of the first two causes and the wide age range of the groups.

The 15 groups agreed that their present access to scientific activities is non-existent. They claim that the only channels to science they have ever had were TV, radio, and newspaper outlets, but these presented science in a way that they could not understand the concepts in their entirety.

All participants on the test agreed that they are segregated from scientific culture. Thanks to our talks, they were able to have a deeper and more direct understanding of the phenomena that we presented to them, according to their needs and comprehension.

Dedoscopio Working for and with the Community

Through these years we realised the importance of associating with different entities such as non-profits, NGOs, astronomical observatories, and government corporations. These partnerships allow astronomy to reach the Chilean BVI community in a more effective way and the science becomes as accessible as it can be (Figure 3). We needed outreach beyond what our small team could do.

Outreach to Teachers

We have visited five schools to speak with primary and secondary school teachers. We show our material and discuss how they can modify them to represent other natural phenomena beyond astronomical ones. Through these discussions the teachers are now able to teach a physical process in a low-cost, tactile way to a student who is BVI while showing the sighted classmates how to be inclusive.

Outreach to Professional Astronomers

Another important activity we have developed is to show our material and work to astronomers at different scientific congresses. In a tactile talk or workshop, we demonstrated our work by covering their eyes and asking them to identify astronomy concepts with only their hands. We helped them realise that adding an inclusive activity to their outreach better conveys an astronomy idea to everybody, no matter their abilities.

Bridging with Other Groups in Accessible Astronomy in Chile

Dedoscopio is not the only project working on accessibility within astronomy in Chile. A lot of outreach practitioners have created tactile models with different materials and goals[2] in the last five years. Because of this, we have collaborated and shared material with other tactile projects. With their work, we have been able to include the stellar formation by Astro UDP[3] and the different types of galaxies from the AstroBVI Kit *(Argudo-Fernández et al., 2019)* in our talks.

Using Solar Eclipses to Promote Astronomy as an Inclusive Science

In 2019 and 2020, we took advantage of the two total solar eclipses in Chile to reach more BVI communities within the country. In 2019 we carried out Eclipse Curioso: Una Actividad Inclusiva (Intriguing Eclipse: An Inclusive Activity), a talk series which helped attendees see astronomy as an inclusive science in the city of Concepción. Through short talks the audience learned how solar eclipses have impacted different historical events, the eclipse-related rites of the indigenous Mapuche people, the mathematics behind an solar eclipse, and the precautions we must take when looking at a solar eclipse.

One highlight of this activity was the talk about the Mapuche's cosmovision. The Mapuche people are the largest indigenous community living in Chile and their culture is different from Chilean culture at large. With the inclusive aim of Dedoscopio, having this talk showed the importance of the Mapuche with relevant astronomical information, like the meaning of the Lai-Antü ('eclipse' in the Mapudungun language) and other celestial phenomena to the culture.

We invited the whole community to be a part of this talk series so we brought in a Chilean Sign Language interpreter, printed 3-D tactile materials for the audience, and secured space for attendees with wheelchairs. More than 150 people enjoyed this activity and were grateful for the inclusive considerations.

In 2020, due to the COVID-19 pandemic, with the support of social and governmental institutions, we sent Kit Eclipse Curioso (Intriguing Eclipse Kit), a box of tactile astronomy materials, to 142 families with one or more BVI members located in the pathway of the total solar eclipse in southern Chile. The box had five tactile experiences to explain the following ideas: sizes of the Earth and Moon and their relative distance, the comparative sizes of the Sun and Moon, different types of eclipses, and the phases of an eclipse. For families with children, we also included the Abre Tus Sentidos a los Eclipses: Sudamerica (Open Your Senses to the Eclipses: South America) book *(Runyon et al., 2019)* and the Lightsoud device *(Hyman et al., 2019)*. We contacted the families via Zoom or Youtube to explain how to use the materials with precaution and answer their questions before the eclipse.

Conclusions

According to the results of our tactile representation test, most of the BVI participants correctly identified the physical processes in astronomy due to our tactile materials that facilitated its understanding. Although we built these materials for the BVI public, we realized through the feedback of teachers and non-BVI participants that it also works for all public which makes it truly inclusive.

The final part of our questionnaire was about valorisation, where BVI communities present a lot of enthusiasm and we received very positive feedback, as they want to learn more about planets, stars, the big bang and wormholes. They also agreed that they feel distant from science in general. One of our new goals is to encourage other scientists in taking their subjects to new audiences, including people with disabilities.

Through activities for and with the community, Dedoscopio has been successful, not only as an inclusive astronomy outreach project, but also as a collaborative network, raising awareness to the BVI community within society. Thus, after three years of work, we will continue implementing our activities, committed to reaching more places across Chile.

Notes

[1] ARTIUC website: http://artiuc.udec.cl/

[2] Instagram of the Astronomía Inclusiva network in Chile: https://www.instagram.com/astro.inclusiva/

[3] Núcleo de Astronomía UDP website: https://astronomia.udp.cl/es/category/outreach/

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Biographies

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