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Multisensory approaches to colors and shapes

Inclusive science education for people with visual impairments using texturing techniques

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Abstract. This work aims to address the theme of inclusion of blind, low-vision, and monocular people in the context of astronomy. The research consists of the collection of images from different telescopes, such as Hubble, GALEX, and James Webb, in diverse wavelengths, such as infrared, ultraviolet, and visible for the production of textured plates. The objective is to compare these images and observe differences in the structures of the same astronomical objects, when observed in different wavelengths. It is important to highlight that not even sighted people are capable of seeing in infrared or ultraviolet. In this sense, the images captured in these wavelengths are invisible both to sighted people and to people with visual impairments. Based on this understanding, the real images are adapted to highlight the objects to be explored, the text of the didactic material is written with a specialized sans-serif and enlarged font called APHont, the text on the thermoplastic sheet is transcribed into Braille and the adapted images are presented in relief through the use of different textures. The mold texturing is done through low-cost materials. All material is tested, evaluated, and replicated by the Instituto Benjamin Constant, a reference center, at a national level, for visual impairment issues. By providing the tactile experience of astronomical images, the objective is to allow blind, low-vision, and monocular people to explore and understand the universe in a more inclusive way. This approach aims to promote the democratization of scientific knowledge and expand the possibilities of interaction of people with visual impairments with astronomy. The present work seeks to contribute to the expansion of access and participation of these people in scientific and cultural activities related to the field of astronomy, stimulating inclusion and mutual learning between people with and without visual impairments, being inclusive, and not exclusive.

Resumo. Este trabalho tem como objetivo abordar a temática da inclusão de pessoas cegas, com baixa visão e monoculares, no contexto da astronomia. A pesquisa consiste na coleta de imagens provenientes de diferentes telescópios, como Hubble, GALEX e James Webb, em diversos comprimentos de onda, como infravermelho, ultravioleta e visível para produção de placas texturizadas. O objetivo é comparar essas imagens e observar diferenças nas estruturas dos mesmos objetos astronômicos, quando observados em diferentes comprimentos de onda. É importante ressaltar que nem mesmo videntes são capazes de enxergar no infravermelho ou ultravioleta. Nesse sentido, as imagens captadas nesses comprimentos de onda são invisíveis tanto para videntes quanto para pessoas com deficiência visual. Com base nessa compreensão, as imagens reais são adaptadas para ressaltar os objetos a serem explorados, o texto do material didático é escrito com fonte especializada sem serifas e ampliada chamada APHont, o texto na folha termoplástica é transcrito em braille e as imagens adaptadas são apresentadas em relevo através da utilização de diferentes texturas. A texturização molde é feita através de materiais de baixo custo. Todo o material é testado, avaliado e replicado pelo Instituto Benjamin Constant, um centro de referência, em nível nacional, para questões da deficiência visual. Ao proporcionar a experiência tátil das imagens astronômicas, o objetivo é permitir que pessoas cegas, com baixa visão e monoculares possam explorar e compreender o universo de maneira mais inclusiva. Essa abordagem visa promover a democratização do conhecimento científico e ampliar as possibilidades de interação das pessoas com deficiência visual com a astronomia. O presente trabalho busca contribuir para a ampliação do acesso e da participação dessas pessoas em atividades científicas e culturais relacionadas ao campo da astronomia, estimulando a inclusão e o aprendizado mútuo entre pessoas com e sem deficiência visual sendo inclusivo, e não exclusivo.

Keywords. Ensino de Astronomia – Infravermelho: sistemas planetários – Ultravioleta: galáxias

1. Introduction

Astronomy is a fascinating subject, but it can be complex and challenging to teach, especially to people with visual impairments. The use of tactile materials is an alternative to make the learning of astronomy more accessible and engaging. It is possible to create tactile models of planets, stars, galaxies, and other celestial bodies, as well as maps and diagrams to help in understanding the movements and relationships among objects in the universe.

The production of tactile materials for teaching educational content is a way to ensure accessibility for people with visual impairments, allowing them to learn under equitable conditions with their sighted peers. Tactile materials enable students with visual impairments (ADVs) to feel and explore shapes, textures, reliefs, and other characteristics of the objects in question, providing a broader and more concrete understanding of the studied content. Moreover, these materials can be produced in a relatively simple and economical way, using common materials such as paper, glue, EVA foam, fabrics with different textures, beads, etc.

The project "Approaching Colors and Shapes in a Multisensory Way" is developed with inclusive rather than exclusive purposes. We will present a board comparing images in different spectra of celestial bodies, such as Jupiter and the galaxies NGC 1510 and NGC 1512. It will show the differences of the same object under the visible wavelength and under an invisible wavelength, not only for blind individuals but also for sighted ones.

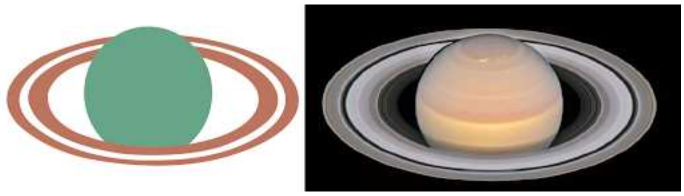

Figure 1. Saturn image (right) and its adaptation by designer Bianca Mello for the Accessible Universe project (left).

2. Metodology

The research in question presents a qualitative approach with field research, using participant observation and semi-structured interviews as data collection instruments. In other words, the results obtained are based on the perceptions of the visually impaired subject involved in the research through the analysis of the didactic resources produced. In this work, we carried out the production of three boards constructed from images of the planet Jupiter observed by the HST (visible region) and by the JWST (infrared), and of the galaxies NGC 1512 and NGC 1510 observed by the HST (visible region) and by GALEX (ultraviolet). For the creation of the boards, several processes and stages were carried out, such as the adaptation of real images, use of specialized fonts, braille writing, color contrast, texturization, and thermoforming.

2.1. Adaptation

The adaptation process consists of capturing the areas or objects to be worked on in the didactic content. This process aims to improve visual accessibility and the understanding of the information contained in the image. In order to overcome the difficulty in perceiving details, distinguishing colors, or identifying complex structures in an image, as we can see in the adapted image and the real image (Figure 1).

The adaptation process is not a direct transposition of a real image into a drawing faithful to every detail, but rather the selection of areas or objects to be emphasized in didactic content. Adapting an image for people with low vision or monocular vision aims to improve visual accessibility and comprehension by reducing visual complexity. For example, in Figure 3.4 we see Saturn's image observed by HST (right) and its adapted version created by designer Bianca Mello for the Accessible Universe project (left). One technique used is reducing the color palette to high-contrast tones, highlighting differences between elements. Adaptation also involves simplifying structures, removing distracting details, and emphasizing key information, thereby avoiding visual overload and facilitating understanding.

2.2. Contrast between colors

Color combinations with strong contrast, such as black and white, improve readability and comprehension for people with low vision or monocular vision. Color theory studies how colors are perceived and combined, and high-contrast use enhances legibility, visibility, and visual organization. The greatest brightness contrast is between black and white, while the strongest color contrast occurs between complementary colors, positioned opposite each other on the color wheel (Figure 2).

2.3. Texturization

The texturization technique consists of using low-cost materials to create relief. Such materials serve the function of providing

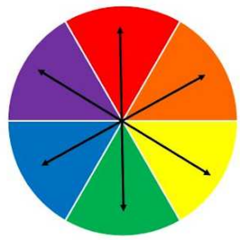

Figure 2. The Color Wheel.

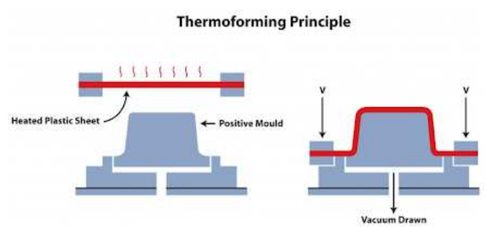

Figure 3. Scheme illustrating the principle of thermoforming.

tactile meaning to the images, with the objective of differentiating structures. The choice of materials for texturization was guided by empirical testing experiences carried out together with technicians and teachers from the Instituto Benjamin Constant (IBC). In this work, special attention was given to using materials resistant to high temperatures, due to the thermoforming process. Offset sheets of 150g, different types of string, papers with various textures, scissors, utility knife, brush, and glue were used.

2.4. Typography and Braille

In this work, the APHont font was used, created specifically for people with low vision by the American Printing House for the Blind. The transcription of texts into the braille system in this work was carried out by the IBC using the free software Braille Fácil.

2.5. Thermoforming

The thermoforming process consists of heating a thermoplastic material until it softens and can be molded into a specific shape. The thermoplastic sheet is placed under the textured matrix sheet in the Thermoform machine. After molding, the material is cooled at room temperature so that it solidifies and retains the shape. The printing of our molds on PVC sheets was carried out under the supervision of the IBC. The thermoplastic sheet already comes out with the legend of the materials, the texturization, and the braille embedded on the sheet.

3. Results and Discussion

3.1. The Planet Jupiter

In this work, we compare images of Jupiter within the visible spectrum taken by the Hubble telescope with the image produced by the James Webb of the giant gas planet in the infrared, a wavelength invisible to both blind and sighted individuals.

The image obtained by Hubble (Figure 4, left) was adapted by designer Bianca Mello for the Accessible Universe project,

Figure 4. Images of Jupiter obtained from the Hubble and JWST telescopes.

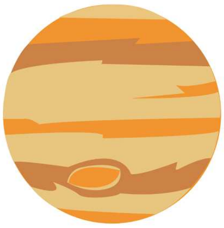

Figure 5. Adapted image of Jupiter in the visible spectrum.

Figure 6. Texturized image of Jupiter in the visible spectrum.

highlighting the different bands (which are the stripes of the planet) and the Great Red Spot, as shown in Figure 5.

Next, we have the adapted image already with textures to be printed, Figure 6. This is a page from the second volume of the tactile notebook of the Accessible Universe project, developed in collaboration with student Érica Behring.

The image from (Figure 4, right) was adapted by designer Bárbara Roly, highlighting the different bands (which are the stripes of the planet), the Great Red Spot, the ring, and the auroras at the poles, which were evidenced by the JWST observation, as shown in Figure 6. In the adaptation process, two different colors of cardboard were used, namely yellow and red, string to symbolize the different intensities of winds on the surface, and corrugated metallic red paper.

With the enlarged image adapted for the low-vision audience, Figure 7, the selection of the materials necessary for texturization was initiated, aiming at its adaptation for blind individuals. The materials must have different textures to represent each of the chosen regions. Below the image there is a legend with each texture, which will be the same used in the texturization of the planet. The legend will help the student to independently understand what each region they are touching means, as presented in Figure 8. Next, Table 4 presents the materials used in the creation of the textures.

As a result of the thermoforming performed on the texturized mold, we obtained Figure 9.

Figure 7. Adapted image of Jupiter in the infrared spectrum.

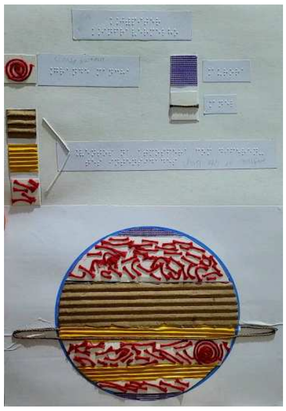

Figure 8. Texturized image of Jupiter in the infrared spectral region.

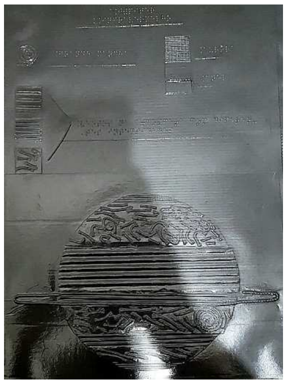

Figure 9. Board of Jupiter in the infrared spectrum.

3.2. Galaxies NGC 1512 and NGC 1510

The differences between the images in the visible and UV regions can also be seen in the adaptations. The details to be highlighted are the more evident bar and a larger core in the image within the visible spectral range, Figure 10. In the UV spectral range, the highlight is on the arms, which are much more extended than what was observed in the visible spectral region, as shown in Figure 11.

Thus, textures were created for both images, and the list of materials used is presented in the tables below. In Table 4.2, the materials used in the visible image and their respective texturization are listed, Figure 4.9. Meanwhile, in Table 4.3, the materials

Figure 10. Adaptation of the image of galaxies NGC 1512 and NGC 1510 in the visible spectral region.

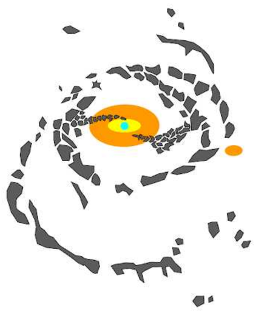

Figure 11. Adapted ink image of the galaxies NGC 1512 and NGC 1510 in the ultraviolet spectral region.

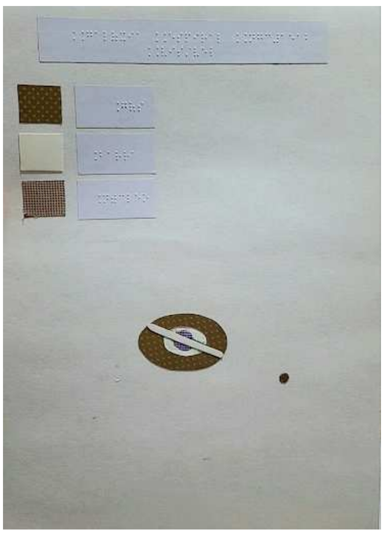

Figure 12. Texturized image of the galaxies NGC 1512 and NGC 1510 in the visible spectrum.

used in the adaptation of the UV image are listed, and Figure 4.10 shows the respective result of the texturizations.

As a result of the thermoforming on the textured matrix, we obtained Figure 4.11 in the visible spectrum and Figure 4.12 in the ultraviolet spectrum.

Figure 13. Texturized image of the galaxies NGC 1512 and NGC 1510 in the ultraviolet spectrum.

3.3. Material Review and Discussion

The material, when used as support for ninth-grade science classes, underwent an adaptation process. Regarding the size of the boards, we considered that this size should allow the material to be handled with both hands on a flat surface. The adapted images preserved the most relevant structures and highlighted the differences found, eliminating less relevant details. The different textures used in each component aimed to emphasize the component in question.

All the material was evaluated by a blind reviewer from the IBC to identify any issues with the texturization and braille writing, as well as to verify whether the proposed material could be understood. Once the material is approved by the reviewer, it can be evaluated in the classroom together with the students. The image below shows an IBC reviewer performing the perception test on the chosen textures of the textured mold.

The evaluation of the material lasted about 20 minutes and was recorded in audio, later transcribed. During the reading of the titles of the materials, the braille was approved, with full understanding of the sentence, including where there are uppercase and lowercase letters.

(Reviewer: This here is Jupiter. [. . .] There is uppercase. [. . .]. Ultraviolet.

During the page layout process, we had to group three different textures and indicate them in the legend with an arrow made of string, which was successfully understood by the reviewer. He identified all the legends with their respective textures. In the analysis of the mold image of the planet Jupiter, the textures were also approved, understanding all the regions and successfully linking them with the legend previously presented.

Reviewer: The planet! Here are the winds. I found the Great Spot, does it really have this shape? [...] Here is the aurora. The aurora we can find. And here. [...] Jupiter's ring is more prominent, right? So it is easier to find.

We can see that the reviewer questions whether, in ink, the Great Spot has the shape of a whirlpool. It is then explained to him that in that specific region of Jupiter, there is a hurricane with high-intensity winds. He also easily identifies the regions

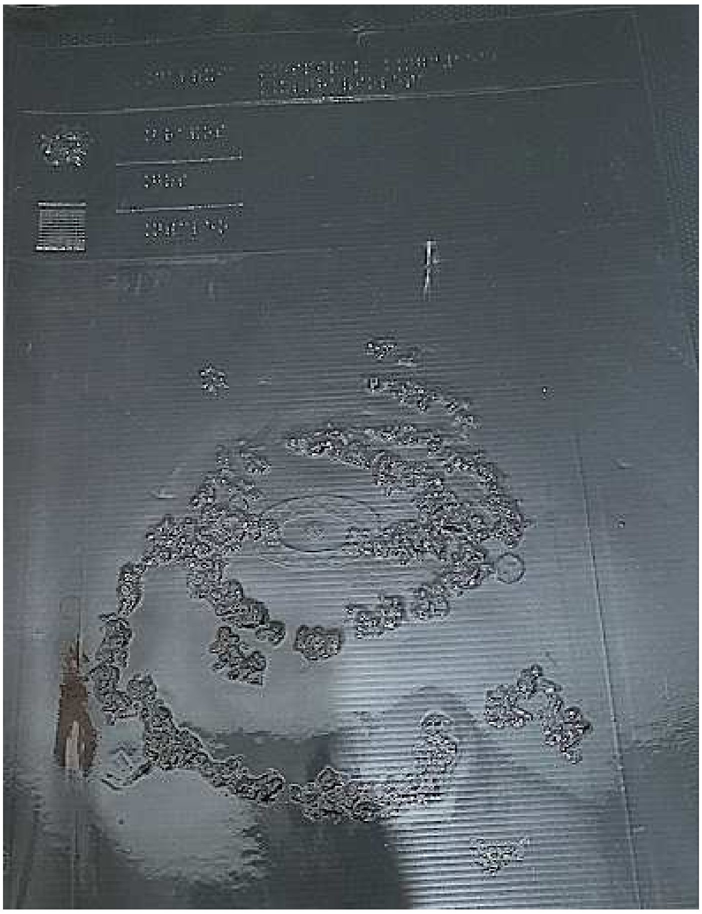

Figure 14. Tactile board of the galaxies NGC 1512 and NGC 1510 adapted in the visible spectral region.

Figure 15. Tactile board of the galaxies NGC 1512 and NGC 1510 adapted in the ultraviolet spectral region.

Figure 16. Three finalized tactile boards.

classified as aurora on Jupiter, as well as the representation of its ring. This demonstrates that the reviewer can easily perceive, through his haptic system, the entire scientific structuring of Jupiter already known by sighted people.

In the thermoformed PVC boards, there was a problem in identifying a texture of the galaxies NGC 1512 and 1510, as it was barely perceptible. The object is small and the chosen texture was subtle. The authors will change it to a rougher texture, as this may be more perceptible on the thermoplastic sheet.

The approval of the different textures used reinforces the proposal of authors such as Cerqueira and Ferreira (1996), that the material should consist of different textures to better highlight the component parts of the model produced, and of Silva and collaborators (2020) when carrying out a faithful adaptation of the didactic resource in question.

4. Concluding Remarks

In light of the issues presented in the theoretical framework of this study regarding the scarcity of inclusive materials for teaching astronomy to students with visual impairments (ADVs) and the lack of preparation among educators when receiving students with disabilities, this work directly addresses both aspects. The conclusion highlights the achievement of the main objective: producing textured plates to support the education of visually impaired individuals, with the purpose of promoting inclusion, equity in teaching, and the training of teachers in the field of astronomy. The materials were positively evaluated by a blind reviewer from the IBC, who approved both the braille and the textures used in their production.

As future perspectives, this material will undergo its final testing stage with Basic Education students at the IBC, which will directly impact the teaching and learning process, just as other resources we have already developed within the Accessible Universe project in partnership with the Science Within Reach group at the IBC.

Bibliography

Dominici, T. P., Oliveira, E., Sarraf, V., & Del Guerra, F. 2008, Revista Brasileira de Ensino de Física, 30, 4501

Werk, J. K., Putman, M. E., Meurer, G. R., et al. 2010, The Astronomical Journal, 139, 279