Proposal for teaching optics to blind people through the workshop called My Hands See

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ABSTRACT

This work shows an alternative approach for teaching basic concepts of optics and acoustics, addressed to people with visual disabilities. We describe in detail how concepts as wave, period, frequency, wavelength, maximum, minimum, amplitude, reflection, transmission, and absorption are explained through adapted experiments. The workshop has been implemented 3 times so far, benefiting 20 people with visual disabilities and 60 people with multiple disabilities. On the other hand, this work also shows some dynamics that can be done with people without disabilities to raise awareness and identify the needs that we have as a society to be inclusive in a sector as important as education. In this sense, this workshop has been attended by 90 people without disabilities of which some of them are currently volunteers in the execution of the workshop. Finally, the work also talks about other ideas that have arisen during the development of this project and how they plan to get going in the near future.

Keywords: Inclusion, Visual disabilities, Blindness, Visual Impairment, Diversity, Equity, Outreach, Teaching.

1. INTRODUCTION AND OBJECTIVE

In the world report on vision for the year 2020, carried out by the World Health Organization, it mentions that there are at least 2.2 billion people who have visual impairment or blindness. It is also mentioned that the burden of eye conditions is greater in developing countries[1]. According to statistics, visual disability, whether it is blindness or vision impairment, is the second most common in Mexico, reaching a total of 2,691,000 people who experience life differently due to this condition[2,3,4].

Living with a disability undoubtedly modifies the way of learning. There are references that mention that the literacy rate for adults with disabilities is barely 3%[5]. The United Nations Educational, Scientific and Cultural Organization (UNESCO) mentions the importance of paying attention to marginalized and vulnerable groups who cannot exercise their right to education. However, it only emphasizes the basic levels, leaving out the middle and higher levels. In fact, this is reflected by the following statistics. In Mexico, 45% of the people with disabilities over 15 years of age have primary education covered, while only 7% have a higher level[6]. This indicates that people with disabilities do not usually receive professional training, resulting in people with disabilities having to perform informal jobs where they even risk their lives[7]. Statistics show that 64.7% of people without disabilities over the age of 15 are economically active, while for people with disabilities only 39.1% is reached[8].

The educational offer for people with visual disabilities is often limited to people who master the Braille system; However, specialists say that this strategy is insufficient because books in Braille are unaffordable and double or triple the price of a common book[9]. Currently there are different technologies that allow people with blindness or low vision to read, almost all of them are reduced to the use of a computer or tablet, in this way people with low vision can apply a zoom to the writings and read with relative ease, while blind people can use a voice reader. 3D printing has also become a tool for blind people, providing custom surfaces and reliefs that they can use to identify shapes or patterns. There are countries where work is being done to generate inclusive education[10]. However, in Mexico these initiatives to reduce the gap in educational opportunities are not yet known or implemented.

It is worrying to note that despite the large number of people with visual problems and the unfavorable forecast of triplication of cases[11], it does not seem that as a society we care about creating accessible alternatives for those

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who in the future will not be a minority. This workshop then arises from this concern, bringing a proposal for people with visual disabilities to have access to experimental physics and identify themselves as people capable of doing science. This workshop is also designed so that people without disabilities can raise awareness about actions that can be implemented in different sectors to start having a truly inclusive society.

2. SENSITIZATION AND PLANNING

The first step to implement this workshop is to sensitize the people who collaborate as workshop facilitators and clarify the main goal of the workshop. In this talk aimed to facilitators, we talk about: the importance of involving different senses in the activities carried out at school, different ways of transmitting an idea depending on whether we are with a person who was born blind or a person who lost their sight, the correct way to approach a person with low vision or blindness, how to introduce yourself, how to keep their attention, how to tell them where to sit and most importantly, and how to respect their autonomy.

This talk begins with simple activities such as getting to know a ruler and a braille stylus. In this way, the volunteers become familiar with the material and its use. They are not required to learn how to write braille, just to identify it and know how a person with low vision or blindness uses it. Some other tools like Talkback are introduced and volunteers are asked to try sending a message on their cell phone using this tool. There is also talk of the existence of PDF reader and screen reader software that allows people with low vision and blindness to read documents and use a computer with relative ease. Finally, two dynamics are carried out, the first where the volunteers are asked to walk around the place blindfolded and using a cane or the guide of another partner who has sight enabled. The second where the members are asked to continue blindfolded and are grouped with the partners that have the same color of shirt, or the same type of fabric in the pants or that are lined up in order of height as shown in the Figure 1. In this figure we can also see that the technique used by the volunteers was to select a member of the team to accommodate them all.

Figure 1. Photographs of volunteers identifying the fabric of their pants and volunteers lining up in order of height.

Everything that is trained with in the preparation talks has the purpose of teaching us to perceive reality in a way that is more like what people with blindness and visual weakness do. In this way there are more realistic proposals on how to implement a workshop of experiments that can be carried out in the contexts described above.

Once we had sufficient knowledge and tools, we proposed two experiments for the workshop in which basic concepts of optics and acoustics were addressed. The experiments and how to carry them out are described in the next section.

3. IMPLEMENTATION

The first activity proposed in the workshop is aimed to transmit basic concepts such as: wave, amplitude, maximum, minimum, wavelength, frequency, and period. This activity is also linked to what we regularly experience in school of first repairing the theory and then doing a practice.

Concepts or Theory

In this experiment, the first thing that was explained is the concept of wave using a didactic material that was generated so that waves with different wavelengths are marked. By marking, we talk about providing the drawing with a relief. Since each wave is raised from the material's surface, people with blindness and low vision can follow the waves by touch, just as if they were reading Braille. Figure 2 shows an example of this material. It is important to mention that this material was generated using a thick sheet and a pen without ink, achieving a suitable relief for a low cost as this material is easy to make and it does not necessary require 3D printing resources. Hence, this methodology guarantees so that the activity continues to be accessible to people with limited resources,
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Figure 2. Didactic material of waves with relief.

Another extremely useful tool for people who are blind or visually impaired are textures. So, for this reason the subsequent activity the participants are invited to touch through the relief as in Figure 2, and place yarn on the marked trajectory. This activity can be seen in Figure 3. In this case, now there is a much more noticeable relief, noticeable by the texture of the yarn. While the participants place the yarn, they must also indicate the points of greatest height and those of less height. We take advantage of this space to introduce the notion of maximum and minimum.

Figure 3. Participants lay yarn over the path of the wave to achieve more noticeable relief.

Now that we have the notion of a wave, of a maximum and a minimum, we can talk about the amplitude and wavelength. We explain that the amplitude is the height of the wave while the wavelength is defined as the distance between two consecutive maximums. In Figure 2, it can also be noted that there are some boxes next to the waves. In such boxes, the participants should assign a texture to each wave to metaphorically assign a texture to each color, as seen in Figure 4.

Figure 4. Texture assignment to each wave.

The materials used for the box filling were seeds and grains. An important part about the textures is that we asked for materials that were from larger to smaller in size. In this way we related the filling of a box to a unit of time. For instance, we told the participants that the box represented one minute. For long wavelengths we assigned large granular textures (beans) and noted that only a few beans fit in the box, for the next wavelength we selected smaller grains (lentils) and noted that they fit a little more than the box we filled with beans and finally for the smallest wave the box was filled with sugar, noting that many grains of sugar could fit in that box, with this we explained to the participants the concepts of frequency and period, saying that the frequency is the amount of grains they put in each square and the period is precisely how much space in the square a single grain occupies.

The participants learned the basic concepts of a wave and to conclude with this activity we mentioned interesting facts about the visible spectrum and the audible spectrum. Some of the topics discussed were: that each color and sound belongs to a specific wavelength, that our eyes and ears can only detect a part of the entire electromagnetic and sound spectrum, respectively. We then conclude this theoretical part by describing some applications of the different wavelengths to which the human being has access. Once the previous activities are done, we started with the experiments as described in the following section.

Concept consolidation experiment.

With any application available to generate sound frequencies we generate sound waves. We explain that the amplitude is directly related to the volume, but we use the following phrase "the amplitude is the amount of sound", making an analogy in electromagnetic waves by saying that "the amplitude is the amount of radiation". Using these descriptions, we eliminate the need to talk about intensity, since it is a more complex property for the participants to perceive. Later we return to the explanation that the wavelength is linked to a particular sound and for the visible spectrum it is linked to a color. Thus, the participants associated a high-pitched sound with the color violet because they identified that a higher frequency means a shorter wavelength. For the case of the visible spectrum, the explanation given is that violet was the color with the shortest wavelength. Similarly, they associated a low frequency, that is, a low sound, to the color red. To concretize what they learned, the participants made and tested a home phone, following the steps below.

1. **Identification and familiarization with the material:** duo teams were formed to have a transmitter and a receiver. The participants took a time of 2 minutes to familiarize themselves with the materials, which are: disposable cups, thread, and a needle. When presenting the needle, the best way to do it must be found without risking physical integrity and without invading the autonomy of the participants. In our case, we opted to put plasticine on the tip of the needle so that they could identify which part could cause damage, as shown in the first image in Figure 5.
2. **Piercing the disposable cups**: this step could be the riskiest if proper precautions are not taken. As previously mentioned, the needles have a plasticine coating on the tip, the participants located the center of the cup and applied pressure to perforate it.

3. **Introducing the thread and tying it**: the participants introduced the thread at the base of the cup as can be seen in Figure 5, and tied it inside. An example of the result can be seen in the last image in Figure 5. This step could be complicated depending on the size of the hole and the thickness of the thread, so it is important to select the appropriate thickness of the needle and thread.

Figure 5. Materials to make a homemade telephone, participant introducing the thread into the bottom of the cup, and visualization of how the knot should be inside so that it does not come out of the glass.

4. **Walk until the thread is taut**: at this point each team member had their cup in their hand, one of the members stayed where they were and the other began to walk with the help of their stick or a guide to a point where the thread was well stretched.
5. **Test the audio reception:** the duo teams invented a code to know who had the turn to speak or to listen, in this case we suggest that they pull the string. For example, if they pulled once, it meant they were going to talk; if pulling twice, it meant that it was their turn to listen, the synchronize in some equipment took longer than in others but it could be achieved. In Figure 7 you can see 2 participants doing an audio reception test. In this image you can also see how both participants want to speak, since they cannot make a signal with their hand that the other can see they need to use a code like we described before.

Figure 6. Test sound reception.

Once the participants tested the operation of their home phone, we will describe the transmission and absorption as follows.

Absorption experiment

Going back to the previous experiment we must say that "The reason why our home telephone works is the way that sound interact with matter. When the sound comes out of our mouth when we speak, it travels through the air until it reaches the base of the glass, where the vibration of the soundwave that we produced with our voice

experiences 3 different phenomena. First, a part of that vibration is reflected, returning to the person who is speaking. Then, another part of the vibration or energy is absorbed by the base of the glass, meaning that a little of that sound remains trapped. Finally, another part is transmitted to the thread. Here, if the thread is tense it will begin to vibrate until it reaches the base of the glass of our partner, where it is will have the same process but now inverted, that is, the energy will reach the base of the glass, a part will be absorbed and another part will be transmitted through the air to reach the ear of the receiver".

In this explanation we emphasize that materials absorb, transmit and reflect different amounts of sound energy. We can exemplify speaking through a cement wall and a Styrofoam wall. Even if it is the same person speaking, trying to maintain the same tone and volume conditions the result that we eared on the other side of walls was different. We also mentioned that smooth and solid materials benefit sound reflection, while porous ones absorb more. Here we give the example of echo or reverberation in a room that only has walls and how this echo is extinguished when we fill the room with wooden furniture or put curtains that can absorb a certain amount of sound.

Now let us remember that our intention is to address the study of optics, so we say that "in electromagnetic waves the absorption is related to the material, but also to the color, since an object has color due to the wavelengths it absorbs and the wavelengths it reflects". In this way we will identify that an object is white when it reflects all the wavelengths, and it is black when it absorbs all the wavelengths. Absorption implies heating, because a material is receiving energy, and the more energy an object has, the faster the particles move making the material to heat up. To consolidate this knowledge, we developed the following experiment.

1. Participants were given 3 different colored balloons and asked to inflate them themselves. Additionally, they were asked to inflate the balloons to more or less the same size. The participants used touch to identify the size of the balloons.
2. The next step was to attach the balloons and place them in a place where the participants felt warm, as shown in Figure 7.
3. We waited 3 to 5 minutes and the team of volunteers returned the balloons to the worktables, the participants touched the balloons as seen in Figure 7, and identified that one of the balloons was hotter and also that one of the balloons was colder. So, they could figure out which was the black, the white and the extra balloon.

Figure 7. Balloons of different colors exposed to the sun and participants identifying the color of the balloons through touch.

With this experiment we concluded the workshop and we started with a question session.

Question session

Participants show interest in the relationships that exist between light and sound, and they make interesting questions. Some of the questions made are:

- Is it possible to transform every wavelength of light into sound?

- Can you create a sensor that detects the color of things and translates it into sound?
- What if the cups we used in the phone experiment are made of a harder material than plastic?
- What happens if the wire of my telephone is very long?
- What materials absorb more light?

We try to solve their questions and we also take note to include information in the following workshops or activities.

4. RESULTS

4.1 Event impact

This Project has had an impact in various ways. Firstly, it has given the blind and visually impaired community the opportunity to get involved in scientific experiments, generate hypotheses, and test them. With this workshop, approximately 20 students with blindness and low vision have been benefited. Besides that, around 60 students with multiple disabilities, that is they have two or more disabilities where one of them is physical and the other is sensory or intellectual, have also participated in this workshop.

This workshop has also reached to 90 people without disabilities who have been asked to put on a blindfold to simulate loss of vision, this in order for people to experience at least for a few hours the way in which a visually impaired person interprets life. With this, new ideas about accessible activities for the visually impaired population have emerged.

Finally, the workshop has managed to create awareness among the volunteers or workshop participants. In their first meeting where they are prepared to give the workshop, they are concerned about the difficulties that may exist. Later, when working with the population to whom the workshop is directed, they realized that what they imagined does not reflect the number of difficulties that people with disabilities face every day derived from a lack of planning; more and more proposals are received for subsequent activities that are accessible to various communities.

4.2 Future work

Following the bases of this workshop, ideas have been raised that are expected to be implemented in the near future.

a) Make homemade telephones that have cups of different materials, so that the participants can identify variations.
b) Talk about modulation by changing the length of the thread with which the vessels are attached.
c) Use a metal with a paint coating in different colors to do the absorption experiment.
d) Coat the inner walls of the vessel with different materials to see how it affects communication.
e) Create acoustic waveguides that allow to attenuate or amplify certain frequencies and, in this way, explain how a waveguide works in optics and how it has helped telecommunications.

These new ideas have been suggested to corroborate some of the hypotheses raised by the participants and thus have a more complete workshop.

5. CONCLUSIONS

The planning and execution of this workshop allowed us to gather two types of conclusions, those of the participants and those of the volunteers. The volunteers conclude that if they had not participated in this workshop, it is possible that they would never have realized how inaccessible education is for people with disabilities and how from basic levels the proposed activities exclude this population from scientific knowledge. This workshop managed to sensitize the volunteers and now one of their objectives is to make their workshops or conferences

accessible to people with disabilities. The volunteers also mention that they feel motivated to be part of the solution and begin to generate changes in society in terms of the spaces assigned to people with disabilities in sectors such as education and politics.

On the other hand, the workshop was very well received in the population with multiple disabilities and allowed the participants to identify themselves as people capable of doing science. Participants developed and tested their own hypotheses, achieving the purpose of a scientific experiment. The participants mentioned that the difficulties they faced during the workshop are only a consequence of the lack of practice, since they had never participated in a workshop like this before. However, they assured that if these workshops were conducted periodically, they could develop the skill required to conduct them without any inconvenience.

Finally, the participants who do not have intellectual disabilities were able to retain the concepts, relate them and explain them in their own words, so we conclude that the workshop was successful.

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