

# Astronomy for the Visually Impaired

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## Abstract

There are certain disparities between education for the sighted and education for the visually impaired, especially in STEM and more specifically, astronomy. While these disparities can arise from a lack of resources to cater for the needs of the visually impaired, they also arise from the perceptions and attitudes of people. The potential for the creation of a Hertzsprung-Russell diagram which can be accessed by the blind and visually impaired was explored while examining a chapter for a tertiary level astronomy book written by Dr. Wanda Díaz-Merced and her colleagues. The HR diagram concept proposed was found to be a feasible idea which could change the way students are taught tertiary level astronomy, making it much more interactive and inclusive of individuals with visual disabilities.

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## Introduction

The science council defines science as, “the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence.”, however it may be observed that this definition inadvertently excludes certain areas of science, like astronomy, which primarily focuses on that which is not from our world, it is too narrow of a definition for a term as broad as science (Science Council 2019).

Long before medieval times, humans would look up to the stars and observe them, trying to understand the universe around us better which gave way to the creation of early calendars and time-keeping methods, such as sundials. This simple act of observation of the sky and universe could be called astronomy, however, it is much more established in modern day times and countless astronomical achievements have taken place since those times. Despite its growth in complexity over time, NASA simply defines astronomy as, “the study of stars, planets and space.” (NASA 2011).

One could think of science as diverse with respect to the number of different fields of study it contains, STEM being one of the most commonly used acronyms for Science, Technology, Engineering and Mathematics, which refers to those and all areas under those four disciplines. However, when the topic transitions to the diversity of the people within STEM, this is not as elementary.

For example, the increased representation of women in STEM, is a very recent and still on-going mission due to STEM traditionally being a male-dominated sector or field and young women were often discouraged from seeking a career in a STEM field, depending on varying cultures it still happens to this day. “While 12% of women in bachelor programs will graduate with a STEM degree each year, only 3% go on to work in the STEM field. This lack of gender balance has also led to a pay gap between men and women in STEM. According to the Australian Bureau of Statistics, the gender pay gap in STEM fields in Australia was 30.1% in 2013.” (OCallaghan 2017).

## Introduction (continued)

However, while this is doubtlessly a pertinent matter to continue to address and strive towards a more gender equal STEM environment, this endeavor should not stop at gender equality. It is of utmost importance that not only equality for all is achieved, but all-inclusive equity should be accomplished. The difference is simple; equality ensures that each individual or group of people is given the same (or equal) opportunities, whereas equity involves the recognition that different people have different and varying needs and seeks to allocate the necessary resources to each individual or group as required to reach an equal outcome (Lopez 2021).

An example of one area where equity should be given more attention is the inclusion or accommodation of individuals with disabilities in STEM. Science should be a field accessible or available to all, but it is very limited in its accommodation of individuals with varying disabilities, like the visually impaired. It can be difficult to instruct or deliver educational content to an individual who is visually impaired without the prerequisite conditions in place, hence the need for equity rather than equality.

One cannot expect equal learning outcomes between a person who is sighted and one who is not if they are not given what either person specifically needs. Obstacles arise from areas of study that are highly graphic or visual-oriented, how can a teacher provide the same quality of learning for an individual without the ability to view the graphical diagrams? The answer is simple, changes must be made to present these diagrams in a way that is feasible for the individual to visualize, for example, by making it more tactile. Similarly, resources should be allocated so that textbooks can be converted into braille so that these tools for learning can be available for the visually impaired.

However, what does one do if they are interested in a visual-oriented field like astronomy? Astronomy is highly dependent on observation of space, as mentioned in the NASA definition of astronomy. How can allocations be made for an individual who is visually impaired to pursue a career in astronomy and have opportunities as equal as one who is not visually impaired? This report aims to determine the accessibility and quality of education in the field of astronomy for individuals who are visually impaired.

## Literature Review

The issue of inequity is one that is prevalent anywhere from the education system to the world of work. A solution to such a widespread issue can seem out of reach, however, through understanding the issue better, a conclusion can be reached.

The United Nations describes inequality as “the state of not being equal in status, rights and opportunities.” (United Nations 2015). “Inequity is unfair social justice—systematic differences in the health status of different population groups that have significant social and economic costs both to individuals and societies.” (Das et al. 2021). For a multi-cultural STEM environment, or a STEM environment which can accommodate all individuals regardless of their backgrounds, inequity must be dealt with and removed from the system.

“Many teachers and faculty are unaware that through conscious and unconscious words or actions, they are delivering micro-messages along with course content.” (Morrell and Parker 2013). They then gave the example of, “when a faculty member supervising laboratory experiments assigns the role of note-taker to female students, he or she may subtly imply that women are more capable as scribes than as scientists.” (Morrell and Parker 2013). This further solidifies the notion of how critical it is to be mindful of the effects of these micro-messages on the students who may be part of a minority. These effects can be extremely damaging for their self-esteem, especially in STEM, leading to lessened feeling of self-worth and overall low self-esteem in one’s career.

A study done by Marion Allen had revealed a bitter reality felt by many visually impaired individuals as she relays a statement made by a (at the time) 60 year old woman who had been an operating room technician, “At diagnosis, it didn't upset me at that moment, 'cause I felt I am working, I still have a little time. But it really hit me bad when it took extra seconds for me to get things [OR instruments] into focus. And the very, very hurting moment was when I was asked to resign...” (Allen 1989). Those who are privileged with healthy sight may take for granted how many opportunities it affords them, but, for those whose vision is impaired, the world becomes a very limited place,

## Literature Review (continued)

several careers immediately become unattainable and many aspirations must be shelved. No one deserves such a dreary reality.

On the contrary however, another study found that there was satisfaction with the workplace for the visually impaired employees, “Most of the visually impaired people in this chapter report a high level of job satisfaction, although mobility problems, access issues and negative attitudes are reported by most people. Hannah and Sally comment on the flexibility that work in higher education provides.” (French 2017). This shows that it is possible to achieve equitable environments where the visually impaired can work as efficiently as a person that is sighted, though it also highlights the need for a change in the negative attitudes of persons in the workplace.

“Many countries in the WHO South-East Asia region have achieved a great deal thanks to the leadership, commitment, dedication, hard work, and support of many. However, children are still becoming blind and are remaining blind despite effective strategies for control due to lack of adequately trained and equipped eye care personnel and teams, and lack of accessible primary eye care for children.” (Gilbert et al. 2021). While efforts have been made to control the problem of blindness occurring in children, this article highlights the lack of resources (adequately equipped and trained professionals) which had reduced the efficacy of these efforts. It is clear that more must be done to make the necessary equipment available not only for eye care but for the comfort of those living with visual impairments.

A study done by Ami Rokach, David Berman and Alison Rose aimed to qualitatively compare the dimensions of loneliness between the blind and visually impaired with the general population. “As expected, the visually impaired scored significantly higher than the general population on the Growth and development subscale.” (Rokach, Berman, and Rose 2021). This study was conducted through a survey, in which one hundred and eighty-seven people participated in. They cited many articles which highlighted how individuals who are diagnosed with visual impairment may experience anxiety, worry and concern for their future, even depression.

## Literature Review (continued)

So far the previously mentioned information has been general, what about how visually impaired students are affected by the current education system's methods? An article by Blake Colclasure, Andrew Thoron and Sarah LaRose discussed the delivery of education for the visually impaired in the context of agricultural students. Contrary to expectation, rather than expressing how difficult it would be for a blind or visually impaired individual to participate in such a hands-on discipline like agriculture, the article explained that students with mild visual disabilities (circumstances would vary) may access equal learning resources as those without disabilities.

They went on to say that a legally blind person would likely use a paraprofessional for assistance in the learning environment, however, "the use of a paraprofessional in the learning environment does not substitute all roles of the classroom teacher. The teacher must work with the paraprofessional, the student, and members of the student's IEP team to identify appropriate modifications for the learning environment." (Colclasure, Thoron, and Larose 2016). This complements the concept of a need for equity as that is precisely what they described, an equitable learning environment which can change to meet the needs of individual students.

However, to remain true to the essence of this report, teaching of the visually impaired in STEM fields must be considered. Can students with visual impairments or blindness understand graphs with similar efficiency as their sighted peers? A report done by Ashley Nashleanas relays the experience of teachers of visually impaired students, "For example, Nattie articulated her perception of why her student, a male with total blindness, was able to work well with graphs in her geometry course. She attributed his success to his ability to keep math concepts in memory and utilize assistive technology that he knew worked well for him in the past" (Nashleanas 2021).

Another teacher said that the success of her students depended on the joint effort between teacher and student to work towards the student's independence (Nashleanas 2021). The impact of a teacher on the performance of a student greatly increases when the context

## Literature Review (continued)

shifts to that of a student with visual impairment, it is crucial that they receive the resources they require to learn with the same efficiency as their sighted peers.

Another pertinent question to answer would be, what are these ‘resources’ that are needed by the visually impaired? How available or accessible are they? “The Visually Impaired System (VIS) supports this process by providing key facilities a short-range system for detecting obstacles, a short-range system for identifying obstacles, a signboard recognition system, and a shortest path guidance system for source to destination. Obstacle Detection, Distress Calling, Global Location Tracking, Voice Command Functionality & Shortest Route Guidance are all real-time features of this system.” (Bulla et al. 2020). The cited article describes the creation of a program that would enable a visually impaired person to safely interact with the world without the need for traditional assistance methods such as a cane, or guide dog. While this is without a doubt a great feat, the issue of accessibility remains. Similar equipment, such as the eSight 4, averages at a cost of six thousand U.S. dollars (AdaptiVision 2020).

“A person who is visually impaired can capture the image by pressing the volume down button of the smartphone which can be easily found using touching or letting the image being auto-captured. A notification sound will be played to keep on alerting the user about the process of the application. The text of the image will be converted as audio so the user can read the printed material by listening without the use of sight. However, it is only limited to detect English word and work fine in no format printed material.” (Nadhir Ab Wahab et al. 2021). This is a much more accessible method as it simply requires the user to download the text reader app onto their smartphone, however, as stated in the quote, the text reader is limited to English words.

Finally, a study by Noreen Grice revealed the disparity in learning material for the visually impaired as compared to the sighted. Having been told by a group of blind individuals that a planetarium show ‘stunk’, this compelled Noreen to try to determine what could have gone wrong at the show. When I asked if there were any astronomy

## Literature Review (continued)

books in Braille, they guided me to a tall bookshelf where I saw rows and rows of binders: books by Isaac Asimov. I pulled some down to examine them. "Where are the pictures?" I asked. The librarian explained that raised pictures were rare because they were expensive and time-consuming to produce. At that moment, I understood what had happened in the planetarium. The group did not enjoy the show because they had no access to the visual images on the dome." (Grice 2004).

Noting the evident injustice being done, Grice began to personally develop a book for astronomy which would be accessible to people who are visually impaired. She would often ask for feedback from blind individuals that she met in the museum she worked at, she wrote, "If I saw a blind person in the Museum, I would run over and ask if they had a moment to examine something and give me their opinion. Not one person ever refused. They always said they were happy that someone wanted to know their opinion." (Grice 2004).

Her book 'Touch The Stars' was published by the Boston Museum of Science in 1990 and the first edition released with, as she described, "44 large print/Braille pages along with 11 tactile illustrations. Four hundred copies were printed. With no real marketing, just advertising by word of mouth, all of the copies sold out within a couple of years." (Grice 2004). Since then, her work continued and subsequent editions of 'Touch the Stars' were published.

## Method

A chapter by Dr. Wanda Díaz-Merced and her colleagues, constructed to be part of a tertiary level book on astronomy, was examined and edited. In doing so, the issue rose of how to represent diagrams, specifically the Hertzsprung-Russell diagram. Proposed methods included the use of tactile representation of the diagram, the use of audio responses to interact with the diagram and even temperature varying regions to depict scaled down versions of the heat that the different types of stars would emit.

For the tactile representation, which was the most feasible given the lack of resources, the diagram would be made in such a way that the axes, scales and labels would be able to be touched as they are represented as raised points on the diagram, it may be both in braille and standard English to cater for sighted individuals as well as non-sighted. The left and right axes would be absolute magnitude and luminosity respectively, and the top and bottom axes would be temperature and spectral class respectively. The scales of these axes would correspond and thus an indented gridline could be used to connect them, resulting in ease of navigation of the diagram for an individual who is not sighted. The regions on the diagram with star types would be depicted by semi-sphere shapes which would vary in size according to the scaled down size of the stars, showing which ones are smaller and which are larger.

The tactile representation works well with the concept of being within a book, however, with more ideas also came the notion that a separate kit or version of the diagram that is not confined to a book would be necessary. This version would include everything in the tactile version, but, it would have some added features. The semi-spheres would function as buttons instead of being static, which allows for individuals to press the buttons and receive audio responses which can give brief detail of the star.

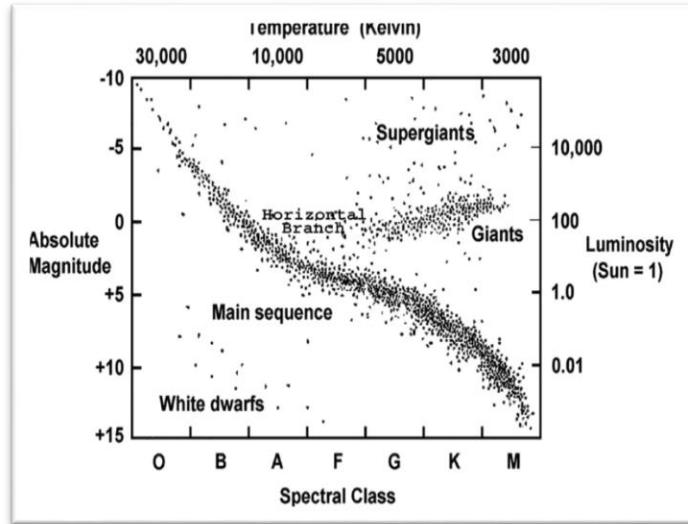
These semi-spheres would also be able to emit heat when the device is on, to show the way heat varies among different star types. The heat would not be painful, only enough to represent temperature difference among stars, which would be accomplished by the use of circuitry within the semi-spheres, much like the concept of heating a copper wire.

## Method (continued)

For a proof of concept, an HR-diagram which fit the axes specifications mentioned previously, was printed out and using a blunt tip of a pen, indentations were made to the paper for it to mimic the tactile version.

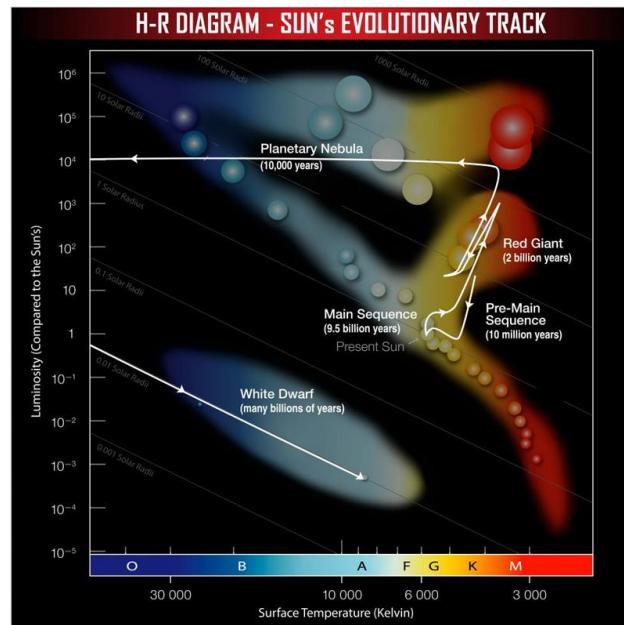
## Results

Figure 6.1 depicting the Hertzsprung-Russell Diagram



(Source of image unknown)

Figure 6.2 depicting the Hertzsprung-Russell Diagram with varying star sizes and temperatures



(Source of image unknown)

## Results (continued)

The concept of the tactile HR Diagram was tested when Figure 6.1 was printed out and light indentations were made on either side to represent the bumps and indents that the finished product would have. However, this was not visible and could only be felt.

## Discussion

From the test that was done, the concept of a static tactile diagram was shown to be feasible as the technology required was already existent. The design is such that the gridlines would be indentations, the diagram surface would be unaltered and the semi-spheres would be like humps that can be felt. The labels and wording on the diagram would be in braille and have the printed English equivalent beside it. All captions would be at the top of what they are captioning so that visually impaired or blind individuals would know what they were examining.

The concept of the individual diagram which would function as an interactive kit was also deemed feasible as the technology required for audio responses can be as simple as the technology used in an audio greeting card which plays upon opening the card, modified to trigger on response to a semi-sphere being pushed with enough force. The force required to trigger the audio response should be great enough that it would not accidentally trigger unintentionally while the students are touching the surfaces.

The hot and cold regions which are meant to depict the temperature variation of stars could be accomplished by the use of high resistance wires of varying resistances so that they would heat up to different temperatures. These wires would reside within the diagram and the heat would radiate to the semi-spheres to be felt safely by the user. However, testing to verify that idea would function with certainty could not be done due to a lack of access to the requisite resources.

In Trinidad and Tobago, the majority of career aspirations of young students can typically fall into either engineering, medicine or law. The portion which actively aspires and pursues a career in astronomy can be comparatively smaller, the portion which pursues astronomy and is blind or visually impaired is very scarce. However, this does not mean that there are no blind or visually impaired individuals who dream of the chance to observe the stars. In fact, the awareness and technology relating to the enabling of the visually impaired to be able to not only pursue academically, but also participate in practically, the field of astronomy, must be spread further and made more readily available.

## Discussion (continued)

Projects such as this one, the creation and conversion of a tertiary level book on astronomy to be accessible to both the visually impaired and the sighted, are critical in making progress towards making the field more equitable with reference to individuals with visual disabilities.

A great example of an individual with a disability being able to contribute immensely to science would be Stephen Hawking, who was an English theoretical physicist that put forward a theory of exploding black holes, which drew reference to both the theory of relativity and quantum mechanics. In the 1960s he had contracted Amyotrophic Lateral Sclerosis (ALS), which is an incurable degenerative muscular disease. Despite the disabling effects of the disease, he persevered through his work and made numerous contributions, which earned him several exceptional honours (The Editors of Encyclopedia Britannica 2019).

## Conclusion

There is a great deficiency in the availability of resources for the visually impaired to equitably pursue a career in astronomy. The lack of different modes of education delivery to cater for individuals with disabilities could certainly be rectified with existing technology and the creation of accessible modes would provide more career opportunities for people with disabilities, not only in astronomy but several varying fields if applied for each discipline. The HR diagram proposed was found to be a feasible idea which could change the way students are taught tertiary level astronomy, making it much more interactive and inclusive of individuals with visual disabilities.

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