A Broad Survey of Inaccessibility and Solutions in Astronomy for Deaf Participants

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Abstract

There is a significant lack of Deaf people participating in astronomy across the hobby, educational, and professional levels. This is likely due to a long list of inaccessibilities and barriers. Through inexperimental research of established literature and primary interviews, this thesis broadly examines and discusses such barriers across various contexts such as inaccessible sounds, the lack of astronomical vocabulary in sign languages, and the ways astronomy curriculum is often not accessible for Deaf students. Possible solutions are discussed with the goal of minimizing the obstacles that keep Deaf people from becoming involved in astronomy and increasing the number of Deaf people in the field. Further research is needed to determine the best solutions, as this thesis acts only as a starting point of an important discussion.

"Any activity can be made accessible with patience, empathy, and creativity"

Rachel Dutton, hard of hearing amateur astronomer

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Introduction

This thesis was written to combine my interests in American Sign Language and the Deaf Community with my experiences being an undergraduate astronomy major. Since I began learning about Deaf experiences, I became far more cognizant of barriers Deaf people face and more interested in accessibility, especially during my astronomy courses here at the University of Virginia. During labs that had me observing in the dark, I pondered how Deaf people who relied on the visual language of signs would be able to successfully navigate such experiences. This project, truly, was born in a meeting with Ed Murphy, a professor of astronomy at UVA, who stated that the department would not be prepared to work with a Deaf student if one was to declare the astronomy or astro-physics major. This showed me how necessary and important this type of work is and inspired me to begin exploring the ways Deaf people might be barred from entering this field and what strategies could be used to minimize such barriers.

Introduction to Deafness: Labels and Language

According to the 2022 American Community Survey conducted by the U.S Census Bureau, 3.7% of Americans have hearing loss. That estimates over 12,000,000 people in America living with some degree of hearing loss. While these numbers include older Americans who experience age-related hearing loss and likely do not identify with deafness, they also include those who are deaf, hard-of-hearing, and “capital-D” Deaf.

As a brief introduction to the labeling practices that will be implemented throughout this paper, “lowercase-d” deaf describes one’s medical condition of hearing loss while Deafness with a capital D is an identity used by those in a shared cultural and linguistic minority group, often most easily identified by the use of American Sign Language, a manual language used by Deaf populations in the United States and Canada. As with any group, labels are nuanced and deeply

personal. Other common labels include hard-of-hearing (HoH), which can be used to describe one with a some level of residual hearing, and late-deafened, which describes one whose hearing loss occurred after the acquisition of spoken language. Note that both hard-of-hearing and late-deafened labels are used by people in both the medical and cultural sense, and are not mutually exclusive. One could consider themself both culturally Deaf and hard-of-hearing, while another could identify as Deaf, hard-of-hearing, *and* late-deafened. In general, the paper will use the phrase d/Deaf as an umbrella term for people with hearing loss both in and out of the Deaf community. When discussing specific figures, the paper will use the correct labeling to the best of its ability.

Some labels, while still used by some, are widely seen as derogatory, and will not be used within this paper. For example, the phrase hearing-impaired is seen as offensive within the Deaf community, though commonly used by hearing people. Additionally, while some deaf people do identify as disabled, many of the Deaf community do not, seeing themself instead as a cultural group rather than a disabled one. In this paper, some sources and statistics will reference disabled people as a whole. As deafness is considered a medical disability in American legislation and is thus included in these statistics, such sources will be included. The inclusion of these resources is not placing the disabled label on anyone. If any person mentioned relevantly identifies as disabled, or any other identity for that matter, it will be noted when they are introduced.

As a final note, it is important to understand the vast differences that exist between d/Deaf people and their preferred communication methods. While many, especially those who are culturally Deaf, use American Sign Language, there are many other communication avenues, or a combination of multiple ones, that people rely on. These include, lipreading, in which words are understood by watching the shaping of one's mouth, speaking, hearing aids or cochlear implants, which may allow some to hear sounds and speech, and various other manual

communication methods. While this list is non-exhaustive, it hopefully provides a look into how d/Deaf people are varied and employ many different communication methods in daily life. As this paper discusses different types of possible solutions, keep in mind that not all solutions will be well-suited for all d/Deaf people.

Significance

As Dr. De Leo-Wrinkler et al. puts it, "astronomy is a gateway into science." Astronomy is a very attractive field, especially for non-science majors in college, 200,000 of which take introductory courses in astronomy each year in the United States. It is a very effective way to get a wide audience interested in science, as it is very awe-inspiring, interdisciplinary, and well-suited for non-professional, community involvement (De Leo-Wrinkler et al., 2016). It is also effective at getting young children and students interested in the sciences and can be adapted to be well-suited for all ages (De Greve, 2010).

Though the involvement, or lack thereof, of d/Deaf people in astronomy is an understudied topic, various statistics can be used to gain an understanding of the situation. In general, hearing people are more likely to be enrolled in bachelor programs than Deaf undergraduate students, who are more likely to be earning certificates or associate's degrees. Additionally, Deaf students have lower college completion rates than hearing students (Garberoglio et al., 2019). Only about 15.5% of d/Deaf people get bachelor degrees in STEM fields, while about 25% of hearing people accomplish this (Trussel et al., 2018). For example, of the estimated 35,000 doctoral degrees awarded in science and engineering fields in the United States in 2012, only about 300 had hearing loss (De Leo-Wrinkler et al., 2019). This is less than 1%, less than half the expected amount based on the proportion of Americans aged 18-34 with hearing loss, which is around 2% (American Community Survey, 2012). This figure is about the same for doctorate recipients specifically in physical sciences, including astronomy (National

Science Foundation, 2015). According to Gallaudet University, working with the National Science Foundation (2012), the portion of d/Deaf people getting STEM Doctorates is far less than the hearing population, at less than 0.2% compared to the 15% of hearing people. Those d/Deaf people who do manage to get involved in STEM fields are more likely to be in roles requiring manual work, such as agriculture and construction, rather than lab or research positions requiring higher education (Trussel et al., 2018). Looking at the numbers, it is clear that there are barriers keeping d/Deaf people from becoming involved in STEM and going on to become STEM graduate students and faculty, as mentioned by Jason Nordhaus (2019), faculty member for Rochester Institute of Technology and the National Technical Institute for the Deaf. He says, "In an ideal world, Deaf students should be able to follow their interests, if they want a physics degree, there should be no barrier in them getting that."

The American Community Survey estimates that 3.7% of Americans have hearing loss (2022). This means that in a perfect world free of barriers, 1 in 25 people involved in astronomy should have hearing loss. Of course, this includes both d/Deaf people, and those with age-related hearing loss that do not consider themselves deaf. Excluding people above the age of 65, more than 1 in 50 astronomy outreach participants, students, and faculty should be d/Deaf. Going through astronomy rosters, is this the case? Though this is not a perfect statistic, it is an interesting point to generate thought regarding the lack of d/Deaf people in astronomy.

What is causing this lack? This paper will discuss various barriers that may explain the discrepancy in d/Deaf participation in astronomy, across outreach, educational, and professional contexts, as well as ways these barriers might be minimized. It is important to focus on accessibility of astronomy, of which d/Deaf people are often "left out" as put by Kate Meredith, president and founder of GLAS Education, an organization committed to making astronomy accessible, in order to allow the 430 million people worldwide with mild or greater hearing loss a

fair chance to join the field of astronomy (World Health Organization, 2023). This paper is not to offer definite solutions to the discrepancy, nor is it meant to be exhaustive. Instead, it is intended to spark an important conversation regarding the challenges an often overlooked population face in daily life and how these might be minimized so they have an equal chance to succeed in the important field that is astronomy.

Procedure

The research for this report was conducted through a combination of established literature and primary interviews with relevant figures. I started by looking into statistics and demographics regarding d/Deaf involvement in astronomy to determine whether or not there was a significant lack of participation. When it was determined there was, the research could continue. Research began by reviewing the literature and different studies and reports already conducted regarding d/Deaf participants and astronomy. While it is not a saturated field of study, there are a few, as will be discussed throughout the report. Many of the reports noted an issue in the lack of astronomical vocab in signed languages. As a result, time was spent examining this in depth. An interview was conducted with Kate Meredith, to discuss this issue.

While there is very little research done regarding d/Deaf participation in astronomy specifically, and was quickly exhausted, there is more regarding STEM fields and disability as a whole. Thus, I examined broader research regarding barriers disabled people (including d/Deaf people) face in STEM fields.

I contacted many people in order to set up interviews on the topic. People contacted included various Deaf astronomy professors from universities across the country, specifically from Gallaudet University and Rochester Institute of Technology, two universities with large populations of d/Deaf students and faculty. Hearing professors were also contacted if they had experience teaching Deaf students. Points of contact were found from articles, faculty pages on

school websites, word of mouth, etc. K-12 Deaf schools were also contacted if they had astronomy classes or clubs. Through articles, various d/Deaf astronomers from around the world were located and reached out to. Various astronomy associations and programs were contacted to discuss accessibility. Additionally, Deaf students in astronomy programs were contacted. In addition to contacting relevant people for direct insights, some published interviews regarding the topic were examined. In some cases, hearing professors were contacted to get insight in their respective specializations, particularly when no d/Deaf person with that experience could be reached.

In addition to my research, I examined the ways various observatories, planetariums and other outreach programs were made accessible. In this research, I contacted Dark Skies Bright Kids, an outreach program operating out of UVA's astronomy department. Additionally, Deaf educational strategies were examined, specifically regarding science classrooms. Deaf historical involvement was also examined.

There are various programs committed to keeping science fields accessible for disabled and d/Deaf people. These programs' literature and resources were examined and some contacted.

Relevant data, interviews, etc. will be referred to as appropriate in the relevant sections below.

Common Issues and Possible Solutions

Inaccessible Sounds

Astronomy is not often regarded as an audio-heavy field. However, there are some sounds that are inaccessible to d/Deaf people, depending on levels of residual hearing. De Leo-Wrinkler et al. (2019) describes the three types of astronomical sounds. The first include natural sounds, ie. sounds that most people can hear without amplification or adjustments, such as a rocket launch. The second are enhanced sounds, which must be modified in order to be heard,

such as low frequency radio emissions from the Sun. The third group includes sonified data, in which non-aduial data is given sound.

However, these only refer to sounds that might face a d/Deaf astronomer as part of academia. There are many other sounds inaccessible to d/Deaf people that might make astronomy participation inaccessible. For example, in astronomy classes, d/Deaf students will often face videos and other educational materials with narration and other audio, not having full access to learning like their peers might. The same goes for astronomy faculty at conferences and similar events. In higher level astronomy classes or professional contexts, places such as observatories and other locations might have alarms or announcements conveyed via speakers, thus not being accessible for d/Deaf people in attendance. Educational and other inaccessible environments are discussed in later sections.

Of course, the most common inaccessible sound that most, if not all d/Deaf people struggle with, is human speech. The vast majority of people across all astronomy contexts hear and speak. This means that conversations with peers, faculty, presenters, etc. will not be fully accessible for d/Deaf people in the field or trying to interact with astronomy.

Many of these issues have simple solutions that could make astronomy much more accessible for d/Deaf children, students, or professionals within the field. For example, a group of researchers designed a workshop in which various astronomical sounds are accompanied by lights and vibrations so that students at a school for Deaf children could also experience, enjoy and learn from the phenomena. The researchers made sure not to include sounds that were too high-pitched for students using cochlear implants or hearing aids. The post-workshop tests showed that the vast majority of students learned astronomy effectively from the presentation (De Leo-Wrinkler et al., 2019).

Similarly, within the classroom, if any lesson materials include audio, sonified or otherwise, it is important to make sure there is also video to go along with it that allows d/Deaf students similar access to the concepts. In contexts where alarms and announcements are presented solely via audio, this inaccessibility could be easily minimized by simultaneously providing the information through a secondary means. For example, AstroAccess, an organization determined to make astronomy accessible for those with disabilities, funded a parabolic flight with a disabled crew. On the flight were two Deaf participants. Where all other crew members could access the verbal announcements warning when they were entering and exiting the parabola, the Deaf members could not. To fix this, the flight used a visual light system that corresponded with verbal announcements– a green light for going into the parabola, a yellow light for coming out, and red light for an emergency. On the same flight, the two Deaf participants also tested haptic feedback watches in which specific vibrations indicated whether they were going in or out of the parabola. By giving the Deaf crew access to the information in ways accessible to them, it allowed them equal understanding of the situation in a way that eliminated the dependency on interpreters, allowing the Deaf participants to exercise the same independence as held by all other crew members. This one program tested two successful and simple methods for eliminating an inaccessibility common in various astronomy contexts. Visual and/or haptic avenues for displaying information could be easily employed in different events, giving d/Deaf participants equal access (NASA, n.d.).

Regarding the inaccessibility of speech to Deaf people, interpretation and ASL will be discussed in more detail in further sections. However, there are ways to make often inaccessible materials and events more easily understood by Deaf participants. For example, in astronomical contexts where a d/Deaf person might be present, such in classrooms with d/Deaf students or in professional events with d/Deaf attendees, it is important to make sure that all materials with

narration are accurately captioned. Live events such as presentations and classes can make use of live transcription softwares that are growing more and more developed. This would allow d/Deaf attendees to read along with what is being presented, even if an interpreter is not present, or for deaf participants who do not know sign languages.

It is important to note, however, that it is common for d/Deaf people to have lower reading levels than hearing people of the same age, especially for d/Deaf students or younger d/Deaf children. This means that captioning and transcription might not always be an ideal or effective accommodation, especially for highly technical astronomical materials (Hintz et al., 2015).

Lack of Astronomical Signs

American Sign Language (ASL), as with all languages, shifts and changes as per the needs of the users. In this case, the users are the Deaf community. The words existing in ASL reflect the communication needs of Deaf signers. For example, in ASL, there are multiple different ways to communicate the words signing or ASL, but there are far fewer music signs for concepts such as singing, something Deaf people less frequently need to refer to. As new communication necessities pop up, new signs get created to fill the holes.

Through this research, one of the most prevalent challenges that many people cited as the largest issue d/Deaf people in astronomy face is the lack of signs for astronomical terms in signed languages. Nordhaus (2019) (introduced on page 7) states that this obstacle of communication is the single biggest barrier that d/Deaf science students face trying to get into their respective fields. Megan Majocha (2022), a deaf doctoral biology student, states that the reason ASL and other signed languages do not have signs for many astronomical concepts is because most d/Deaf people do not need them to communicate. This, however, disadvantages

those d/Deaf people who are or trying to become involved in astronomy (United Nations…, 2021).

Kate Meredith (introduced on pages 7-8) estimates that over 80% of core astronomy terms have no ASL equivalent, and this number is growing bigger as scientific advancements outpaces the development of sign language (University of Leeds, 2019). In these circumstances, the terms must be fingerspelled, which involves using a manual alphabet to spell the terms letter by letter, (Boerner, 2021). For example, in a simple astronomical discussion, one would have to spell E-Q-U-I-N-O-X every time they mentioned the word equinox. While native signers are certainly proficient at fingerspelling, having to do this for every astronomical term that does not have a standard sign (which is most of them) is cumbersome and slows communication. Where fingerspelling is avoided, a colloquial makeshift sign might be used. These are often conceptually inaccurate (Majocha, 2022). This barrier creates problems within varying contexts.

The lack of signs makes teaching d/Deaf students more difficult (Cova, 2009). Fingerspelling difficult concepts is not effective in a classroom where the children might have lower English literacy. Additionally, where makeshift signs are used, students might get confused if the signs do not match the concepts they are learning. As discussed by Meredith, because many astronomical concepts do not have signs, d/Deaf students are not exposed incidentally to this vocabulary from a young age like hearing children are. This not only makes it more difficult for these children to learn these concepts, but there is a lower chance of them developing interest and desire to pursue astronomy.

The lack of signs creates barriers in settings such as planetariums and museums. There might be issues in clear interpreting due to the lack of signs, as fingerspelling would cause the interpretation to fall more and more behind the presentations (De Leo-Wrinkler et al., 2019). Additional discussion will be given to interpretation in the following section.

The lack of signs does not just affect students, however. Derek Rowley, a deaf amateur astronomer states that the lack of astronomical vocabulary in signed languages makes it difficult for all d/Deaf people interested in the field to enter scientific discussions. He states that today, there are more and more d/Deaf people gaining interest in astronomy, and that it is important that sign languages develop to match this need so that d/Deaf people can join in these conversations (University of Leeds, 2019). This likely leads to barring d/Deaf people from the field further: no one wants to spend time in contexts where their contributions cannot be easily acknowledged or they feel alienated.

The lack of astronomical signs in ASL likely also has many secondary effects. It was mentioned above that the lack of signs bars students from developing an interest in astronomy in the first place. Additionally, difficult communication might generate difficult or frustrating situations, dissuading a d/Deaf individual from pursuing the field. As discussed at the beginning of this subsection, language follows the needs of the users– ASL has a lack of astronomical signs because there are not many signers involved in astronomy. However, the lack of astronomical signs in turn bars signers from becoming involved in astronomy. The relationship between these two factors creates a loop, making it difficult to solve.

ASL is not the only language lacking this important vocabulary, there are many groups around the world trying to tackle this problem in their own local languages. Voelzke et al. (2022) discuss the lack of astronomical signs in Libras, or Brazilian Sign language. There are also various groups focusing on this problem in British Sign Language (BSL), the sign language used by the Deaf in Britain. (University of Leeds, 2019).

How is this problem being addressed? A passive way to solve this issue would be to make astronomy more accessible for signers. This would create the communication need that predates all language creation. A more active approach, however, is taken by various groups that

create sets of signed vocabulary for astronomical terms. Many of these groups exist with most of them prioritizing Deaf involvement in the creation. Meredith emphasized that signs cannot be created without the involvement and approval of Deaf signers, who know the language more intimately than anyone outside the culture could ever hope to achieve. Mandy Houghton, a Deaf science teacher, echoes this, stating that it is important for the created signs to follow the linguistic rules of ASL, or else they will feel wrong and not be used (Boerner, 2021). Gary Quinn, a Deaf linguist, states that created signs must be tested to ensure they are easily recalled and understandable (University of Leeds, 2019). It is also important for the signs to be conceptually correct to the concepts they are describing, or else d/Deaf audiences might get confused regarding the concepts. On the other hand, a conceptually accurate sign might make it even easier for d/Deaf people to understand the vocabulary, as they are hard-wired to understand visuals portrayed in signs (Nordhaus, 2019). Some people might doubt the ability to describe complex astronomical concepts in signs, however the people behind the International Astronomical Union (IAU) Sign Language Project assure that it is "capable of conveying" these concepts "with visual brilliance" (United Nations…, 2021).

With so many groups making signs, the decision on which ones will be standardized is completely up to the natural usage of the Deaf community. Some will be picked up, some will be adapted, and others will simply be dropped. As for specific contexts, teachers and faculty need to work with the students to decide which sign will be used within their classroom (Boerner, 2021). These created signs will help minimize the language barriers the Deaf community faces in astronomical contexts by giving them the power to participate in their language, without relying on English spelling. Additionally, Deaf astrophysicist Dr. Olja Panic notes that these signs will finally allow Deaf scientists to give lectures, lead workshops, share their research, and contribute to scientific dialogue freely in their natural language (Braun et al., 2018).

Issues with Interpreting

American Sign Language interpreters have the important and difficult job of closing the communication gap between Deaf and hearing people by interpreting the meaning of messages between spoken language, usually English, and ASL. Interpreters often specialize in specific contexts and are well-versed in the specific vocabulary and knowledge required for facilitating communication in that context. For example, someone who specializes in court interpreting must be knowledgeable on the meaning and signs associated with specialized court vocabulary. The same can be said regarding scientific fields. Deaf scientists rely on trained interpreters for language access in their daily lives (Majocha, 2022). There are a few barriers, however, related to interpreting in astronomical contexts.

For one, it is difficult for d/Deaf people to benefit from interpretation in astronomical contexts simply because there are not enough interpreters trained to do so. There is a lack of technical interpreters trained in scientific fields, so much so that even Deaf NASA employees have faced issues getting technical interpreters. There are a few possible reasons behind this shortage. For example, interpreters might avoid technical jobs because they do not understand the concepts (Schwarber, 2021). Whatever the reason, if there are not enough interpreters to meet the needs of Deaf astronomy students and professionals, these people cannot experience the benefits of communication access that interpreters are meant to provide.

Interpreters also struggle due to the lack of specialized ASL signs for astronomical terms. It is their job to communicate these concepts, a responsibility made far more difficult by the lack of adequate vocabulary for the topics. While experienced interpreters are able to facilitate communication through obstacles such as these, the need to fingerspell or create and explain signs for astronomical concepts takes time, and would likely cause the interpreter to fall behind from what is being said or signed. This brings its own issues into classrooms, especially when

one d/Deaf student is in a lecture that is verbally spoken. The time discrepancy between what is being taught and what is being interpreted, commonly known as lag time, is a very important tool used by interpreters that minimizes errors in the interpretation. However, this lag time can make it more difficult for the d/Deaf student to participate in the class or interject with questions. For example, imagine a professor lecturing about a complex astronomical topic which the interpreter is relaying to a lone Deaf student. By the time the interpreter finishes signing that stretch of the lecture, the student has a question about a concept that is confusing her. The lecturer, however, in the time it took the interpreter to finish signing, has already moved on to the next part of the lecture. The student, then, is left with no time to ask her questions as her attention is required for what is currently being signed. This harms the student's learning and her understanding of the concepts (Braun et al., 2018).

The last, and arguably most important, issue relating to technical scientific interpreters is that those who do exist in the field are not knowledgeable in the scientific concepts that they are responsible for interpreting, according to Houghton (Boerner, 2021). Against common misconceptions, an interpreter does not translate messages exactly word-by-word. Instead, they must understand what is being conveyed so they can best convey the meaning of the message. To be able to accurately interpret in astronomical contexts, then, they must understand the concepts being discussed. If this is not the case, rather than helping facilitate communication, they worsen the communication barrier. Daniel Lundberg, a Deaf scientist who works at Gallaudet University, says he hates attending scientific conferences as the provided interpreters do not understand the concepts that relate to his research, making communication with colleagues cumbersome (Boerner, 2021).

When interpreters do not understand the concepts, the way they interpret the messages will be fundamentally inaccurate. An example of this is given by Nordhaus (2019), who

describes a time he caught an interpreter discussing “three people having a problem” when the lecture was about the interaction of astronomical bodies. Imagine the confusion a Deaf student would have in this lecture if they had no other context on what was being said. This confusion disadvantages d/Deaf students and astronomers by making language access unequal and making it more challenging for them to express their thoughts. Asher Kirschbaum, a Deaf college student studying physics, says that in lectures, the interpreters’ inaccuracies force him to go through a lot of extra work teaching himself the content. Likewise, Gabriela Santos, a hard of hearing cosmology student, notes that students have a harder time grasping scientific concepts when interpreted than when taught directly in ASL (Ayshford, 2019).

When Deaf students give presentations, in order for their words to be shared accurately to the audience, they must take time to prepare interpreters on the concepts and vocabulary used. Deaf students from Gallaudet University share that this responsibility is exhausting, and takes time from their personal preparation that hearing students do not have to deal with (Gallaudet University, 2012).

There are some ways to minimize this unfairness that d/Deaf people face due to interpreter errors. The first is simply to make sure interpreters hired for scientific contexts are qualified. Educational context is infamous for being filled with under-qualified interpreters, seen as a place to gain experience, however, this is unfair to the students affected by this poor service. Even if the interpreters do not understand the specific concepts, before classes, teachers need to work with interpreters to make sure they understand the material, Nordhaus says. Nordhaus (2019) also explains that he is involved in a project that creates short signed videos explaining scientific concepts that can be used by interpreters to understand the concepts and familiarize themselves with common signs they will be required to know for the job. Finally, in a meeting with interpreters, a report from Gallaudet University states that the lack of interpreters

comfortable in technical contexts can be solved with increased mentoring and workshops aimed at preparing interpreters to take these scientific jobs (Gallaudet, 2012).

Discrimination and Prejudice

One thing that might deter d/Deaf people from getting involved in astronomy at the educational, amateur, or professional level is avoidance or anxiety of discrimination and prejudice they often face. In 1975, Deaf scholar Tom Humphries coined the term audism to describe the deeply held belief in greater society that hearing people are superior to those with hearing loss. This belief is held, unfortunately, commonly in the world of academia.

Rachel Dutton, a hard of hearing amateur astronomer, says that discrimination and feelings of superiority are much more common amongst the professional astronomers she has interacted with, compared to her amateur colleagues. She says that "academia often doesn't accept disabilities," with d/Deaf people facing particular criticism. She credits this to part of the reason d/Deaf people might not get involved in astronomy. She says that many people within astronomy are often resistant to accommodating d/Deaf people in the field, and when accommodations do exist, many peers and faculty see them as unfair advantages.

Apurva Varia, a Deaf mission director for NASA dreamed of becoming an astronaut as a teenager when NASA personally sent him a letter saying that they were not ready to accept a Deaf astronaut, and that his dream would not be possible (NASA, n.d.). It is easy to see how such attitudes would dissuade students from continuing into that field.

If students do make it to college-level academia in astronomy, it is common for faculty to have no experience working with d/Deaf students and often hold misconceptions or prejudice about d/Deaf people, which might make students feel unwelcome. Additionally, this lack of understanding might create obstacles in students getting adequate accommodations. Both of these factors might lead to students leaving programs (Braun et al., 2018).

It has been found that disabled doctoral students, including those who are d/Deaf, are far less likely to be given research positions than their nondisabled peers. Additionally, when these students graduate, they may face discrimination when trying to seek employment (Aarnio et al., 2019). When they do find work, disabled scientists and engineers report salaries that are an average of 7.5% lower than nondisabled workers. (De Leo-Wrinkler et al., 2019). Additionally, in professional fields, d/Deaf workers might still face obstacles like attitudes and discrimination from peers and a lack of appropriate accommodations (Gallaudet University, 2012).

As with discrimination and prejudice with any group, this is a nuanced and deeply complex topic. While there are ways to improve individual prejudice of d/Deaf individuals, such as specific training to inform teachers how to best work with d/Deaf students, fixing systematic discrimination such as wage gaps is a more complex challenge. However, this work is important and must be tackled. As Aarnio et al. (2019) state, to make astronomy truly accessible, there needs to be additional mechanisms in place that protect d/Deaf people from discrimination.

Lack of Community and Role Models

This essay explores various factors contributing to the underrepresentation of d/Deaf individuals involved in astornomy. This section examines how that very absence is a factor all in itself. That is, the lack of d/Deaf people in astronomy, caused by the reasons discussed in this thesis, is leading to even more obstacles in d/Deaf involvment. This illustrates the interrelation between the reasons discussed in other sections. Many factors influence one another, in many cases creating feedback loops.

Houghton (introduced on page 16), illustrates the importance of this topic by saying “if you don’t see people that look like you, speak like you, live like you working and doing those things, you will assume it’s impossible” (Boerner, 2021). There are very few d/Deaf people majoring in scientific fields, including astronomy. There are even fewer d/Deaf people that

continue to graduate programs, meaning there is not a community for the students that do (Gallaudet University, 2012). This lack of community leads to even fewer d/Deaf professionals and educators, and the lack of role models and a d/Deaf support system leads to fewer d/Deaf people majoring. Thus, a loop is created which feeds and worsens itself (Boerner, 2021, Nordhaus, 2019).

In academia, only 9% of undergraduate students, 5% of graduate students, and 1% of doctorate students are disabled, including deafness. This is despite the fact that almost 30% of the United States is estimated to have a disability (Aarnio et al., 2019). This illustrates the lack of community d/Deaf people would have as they work towards their degrees. It is also important to note that while disabled people often find community in each other, despite not having identical disabilities, d/Deaf people often do not fit in this community, largely due to the language barrier, further isolating d/Deaf students and worsening this problem. This issue is especially notable because, as Houghton notes, the sciences are very social fields where it is important to discuss ideas with someone, but due to the language difference and prejudice, d/Deaf people are often isolated and without community, to the point where it affects their academic work (Boerner, 2021).

One way to fix the issue regarding the lack of role models is to highlight the d/Deaf astronomers that do exist, both past and present. Dr. Henry Snyder, a hearing professor at Gallaudet University in Washington D.C. with experience teaching astronomy to his Deaf students, states that one way he engages his Deaf students in science fields is to teach about the contributions of d/Deaf astronomers within his lectures. He does so because he understands the importance of like-minded role models, especially for young students. For example,Annie Jump Cannon, John Goodricke, Henrietta Swan Leavitt are all famous deaf astronomers who made great contributions to the field of astronomy (Lang & Meath-Lang, 1995). Historical deaf

astronomers existed in various countries, so highlighting their contributions can be more personalized for d/Deaf children and students in different locations. Even more recent, d/Deaf students would likely find value in lessons about The Gallaudet Eleven, a group of 11 d/Deaf men from Gallaudet University in the 1950s who helped NASA understand the effects of weightlessness on the human body due to their "immunity" to motion sickness, caused by the differences in the inner ear (Almeida, 2017). These men are a great way to increase pride to aspiring d/Deaf astronomers by painting their deafness in a positive light. As one of the men said, they "were different in a way they needed" which allowed them to be of significant help. Furthermore, many of the primary sources included in this paper prove that there are Deaf astronomers today that could be shown to students to prove that their involvement in astronomy *is* possible. Connecting d/Deaf students in astronomy programs to older, professional d/Deaf astronomers is a great way to build community, provide role models, and make astronomy a more positive experience for students.

As for the problem of limited community, one way to effectively solve this problem is to focus on solving any of the other barriers to access focused on in this paper. By eliminating the reasons d/Deaf people struggle to become involved in astronomy, naturally, more d/Deaf people will be able to access the field. This will lead to greater numbers of students of all levels, professionals, and faculty who are d/Deaf, thus creating a greater community of d/Deaf people within astronomy.

Inaccessible Curriculum

If the goal is to increase the amount of d/Deaf people in the field of astronomy, ensuring that d/Deaf students' time in schooling is a positive and accessible experience should be prioritized. Inaccessible schooling might cause students to stop pursuing the field, limiting the

amount of d/Deaf professionals. There are many barriers that d/Deaf students often face during their academic career, both in K-12 education and beyond.

Almost all astronomical classes require English literacy for full access (Rockcliffe & Gozman, 2023). This can prove challenging for d/Deaf students who do not have full access to English. For many Deaf signers, English is their second language, and thus not ideal for learning complex concepts. Even for non-signers, deaf students who were either born deaf or lost their hearing during the learning acquisition stage often struggle with learning English. Thus, d/Deaf students often have lower reading levels, causing students to struggle with understanding STEM vocabulary (Trussel et al., 2018, Hintz et al., 2015). Additionally, many science classes are based on a textbook, which is not accessible for d/Deaf students (National Science Teacher Association, n.d.). Further, any literature-based educational materials might not be well-suited for d/Deaf students as is. d/Deaf students do not have the same morphological understanding that hearing students do. For example, a hearing child will have a better chance of understanding and remembering the definition of constellation as they have a higher chance of being familiar with the morphemes that make up the word. This child will very likely be familiar, or at least have the background knowledge to understand that con- means “with” and -stella means “stars”. A d/Deaf child, however, might not have this understanding of English and likely lacks the incidental learning these connections require. This does not just affect young students. A lack of morpheme familiarity affects the ability to understand necessary STEM vocabulary all the way through college courses. This can be seen clearly in vocabulary words such as exoplanet, geosynchronous, and perihelion (Trussel et al, 2018). This lack of understanding means d/Deaf students must spend more time learning the vocabulary than hearing students do and, thus, might fall behind or struggle to get the most out of their courses.

Other course materials are often inaccessible. For example, many videos are not captioned, and captions that do exist might not be accurate. Even for live transcription softwares, professors might wander away from the microphone, especially in large introductory lecture halls, rendering the accommodation useless (Braun et al, 2018). Dimming the lights in classrooms, common to see visual aids, especially dark photos of the night sky, might make it difficult for a d/Deaf student to see their interpreter or lipread.

The way classrooms are set up and run might also pose issues for d/Deaf students. For example, the typical lecture style class, which is very common for introductory college-level astronomy courses, is very challenging for d/Deaf students. These issues that completely affect the experience of d/Deaf students often go completely unnoticed by hearing faculty. In a typical class, professors often have visual aids such as slideshows that they use to aid in the lecture. It is important to notice, however, that for a d/Deaf student with an interpreter, that student cannot look both at the interpreter and the slides, they must pick between the professor's writing and voice, and they cannot get both like hearing students can (Nordhaus, 2019). The same is said for students using transcription software, made ever more popular with today's growing technology. Likewise, students who rely on lipreading to support residual hearing might struggle if required to look away from the speaker, or if the speaker turns away, like they might if gesturing to a slideshow. Additionally, the further points of visual focus are spatially, the more that d/Deaf students miss. For example, it is common in such classes for there to be a slideshow projected on one wall, the lecturer holding a visual aid in another location, and the interpreter to be standing elsewhere. d/Deaf students must look between these three points, missing much of the information in the cross-time (Braun et al., 2018, Gallaudet University, 2012).

Other aspects of the classroom might make learning difficult. In large lecture halls especially, students' view of the lecturers, the interpreters, or visual aids might be obstructed,

making learning difficult. Additionally, in a class where students often participate, it is often preferred that the d/Deaf student have clear eyelines toward their peers. In courses where materials are not available after the lecture, student's might need to take notes, adding one additional thing that demands visual attention (Gallaudet University, 2012).

Other school-related aspects might cause barriers in a d/Deaf student's learning. Study groups and clubs, meant to further student learning, are often inaccessible due to language barriers (Ayshford, 2019). Students are often left out of group work for similar reasons. Teachers and faculty who have limited experience with d/Deaf students might believe they are doing good by giving students easier assignments or lighter workloads, however, this might create an environment where the student feels inferior or less capable. It is important for faculty to remember that even though d/Deaf students face unique struggles, deafness does not affect mental abilities at all. Deaf people are just trying to learn complex concepts in a language that is not native, natural, or accessible to them and should be regarded just as a Spanish- or French-speaking student might. Deaf students should be given the support necessary to close any language gaps and understand the material without being made to feel like they are less intelligent (Braun et al., 2018).

Astronomy labs might also be challenging for d/Deaf students to participate in fully. Darkness, such as required for observing, makes viewing lip reading or interpreting more challenging. Additionally, students might not be able to bring their typical transcription equipment outside or into observatories. Additionally, while looking through a telescope, reading a labsheet, or focusing on a display, students might miss important information being communicated, as mentioned by Snyder (introduced on page 23).

Students also experience the barriers discussed in other sections. Interpretation issues, prejudiced attitudes, and lack of community might also affect the experience of a d/Deaf student inside the classroom.

Many issues discussed in this section could be minimized with increased awareness in faculty to d/Deaf needs. Many of d/Deaf students' needs and issues are often gone unnoticed or are not immediately obvious. To illustrate this point, Nordhaus (2019) shares an instance of one Deaf student deeply thanking him for not having facial hair, as it makes lipreading much easier. Nordhaus expresses his surprise at this, saything that he never would have considered that factor on his own. Some possible improvement will be discussed here, however, teachers should support open communication with their students and be willing to make changes in their own classroom or help the student advocate for changes needed in their accommodations (Braun et al., 2018).

As discussed, information presented solely in textual and verbal formats is not best-suited for d/Deaf students. To ensure that information is being presented in an accessible manner, many d/Deaf people and educators suggest that classes prioritize multimedia-based learning. d/Deaf students navigate the world through their eyes and, thus, learn best when information is presented visually (Bolat, 2016). Against common misconceptions, d/Deaf students have no barriers to understanding complex concepts as long as they are presented visually, says Nordhaus (introduced on page 8). Ensuring that information is presented via multi-sensory methods allows all students to access the information (Rockcliffe & Gozman, 2023). It has been proven that Deaf students can be taught astronomy effectively when taught via multimedia based resources compared to typical lessons (Egelston-Dodd & Ting, 2007). Many groups have worked to develop various multimedia based educational resources well-suited for teaching d/Deaf students astronomy. Some of such resources will be described here to hopefully inspire potential changes

that can be made in classrooms with d/Deaf students. Bolat (2016) developed a series of activities well-suited for d/Deaf students focused on visuals, videos, interactive visits such as planetarium presentation, and hands-on activities using tactile models. Pre- and post- test scores were compared, concluding that these activities were effective at teaching these students astronomical concepts. Additionally, due to the fact that the students in the study were all from a Deaf school, the instruction was all given in ASL, which may or may not be plausible for other astronomy classes.

Egelston-Dodd and Ting created a web-based astronomy class for Deaf students at the Rochester Institute of Technology in New York. Part of the course was taught online via the common slideshow with graphics and text, but synchronized with corresponding ASL videos. In class, students participated in a hands-on laboratory activity led by a signing instructor. Data analysis concludes that students taught with this method earned higher grades than previous classes not taught with the multimedia methods.

In a more unique example of multimedia astronomical education tools, Nordhaus et al. (2020) tested AstroDance, an artistic educational performance that teaches about gravitational waves via dance, theater, and visuals. The performance was shown to both d/Deaf and hearing audiences. Interestingly, based on post-performance questionnaires from 971 audience members, d/Deaf audiences reported a significantly higher level of learned information from the presentation than hearing students did. They concluded the following:

> [Astrodance] enabled DHH [Deaf and Hard of Hearing] audience members to successfully learn from the performance. Compared to most standard scientific presentations with no-signed interpretation, this is an exciting result as it demonstrates one method for actively engaging a DHH audience in scientific outreach (p. 11)

This expresses the significance of multimedial methods when teaching d/Deaf students.

Zamfirov et al. (2007) tested a method for teaching astronomy to d/Deaf students aged 13 and 14 years, concluding that their strategy was effective for educating d/Deaf students both in mainstream (primarily hearing) schools as well as specific Deaf institutions. Additionally, the method can be used for both hearing and d/Deaf children. They developed a CD that taught astronomical lessons through text, illustrations, and videos using Bulgarian, Bulgarian Sign Language, and English. They successfully accomplished their goal of developing a strategy to teach these difficult, often abstract concepts, to d/Deaf students.

In addition to specific avenues of portraying information, there are specific tips educators suggest in order to best teach d/Deaf students. It has been shown that students have higher levels of knowledge of content when taught directly in ASL by a signer, rather than when spoken English lessons are interpreted by a professional interpreter. This is true regardless of whether or not the students are native signers or not (Kurz et al., 2015). While it might not be possible in all environments to avoid interpretation in favor of direct instruction, especially in a classroom that is primarily hearing, it is important to keep in mind that direct signing is more effective for teaching d/Deaf students, especially if using multimedia supplemental resources as described above, many of which include signing lessons.

According to Dr. Henry Snyder (introduced on page 22), multimedia strategies such as those discussed above, are important in effectively teaching d/Deaf students. He emphasizes keeping classes as visual as possible, including vibrations to model phenomena when applicable, and using manipulatives and hands-on activities to teach complex concepts. Additionally, to keep classrooms accessible to d/Deaf students, it is important to make sure all videos have accurate captions (National Science Teacher Association, n.d.).

There are also specific changes that can be made to the classroom and lesson set-up to increase chances of success for d/Deaf students. For example, because d/Deaf students must be

watching the interpreter to get the information from the lesson, students should be given a notetaker so that they can, instead of splitting their attention between their notes and the lesson, can focus entirely on the interpreter (Gallaudet University, 2012). Additionally, to best set students up for success, classrooms should be set up in such a way that allows the d/Deaf student(s), whether it be one or 100, to have a clear sightline to the lecturer. Not only is this important for the student's understanding, but additionally, teachers, if lecturing with a powerpoint, must be able to watch the eyes of the d/Deaf student(s) to know if they are ready to continue lecturing, or if they are still reading the slides (Nordhaus, 2019). Teachers should also pause between transitions or sections of lessons to give the interpreter time to catch up and allow the student to interject with questions or comments. Additionally students that use transcription, should not be expected to look between their laptop, or other device, and the lecturer. For these students, tracked transcriptions that follow the lecturer might be more successful. If this is not possible, projecting the transcription on the board closer to where the professor is standing not only helps the d/Deaf student, but can be useful to many students (Braun, et al., 2018).

In today's age, online classes via Zoom, or similar softwares, are increasingly common. It is important to ensure that even online astronomy classes are accessible for d/Deaf students, though many hearing people might not be aware of how to best do this. For one, turning on captioning is a helpful way to support d/Deaf participants. Additionally, recording and saving lectures is important to allow d/Deaf students to review material that they may have missed during the class, for reasons such as looking between visual aids and the interpreter. Allowing students to ask questions via chat might help d/Deaf students feel more comfortable asking questions, especially due to issues regarding lag time. Finally, turning off the feature on video softwares that moves people's camera windows around in response to who is speaking is helpful

for d/Deaf students, as moving windows can make it hard to keep track of an interpreter's signing.

For times where astronomy classes must be in the dark, such as when observing, Meredith explained that connecting red lights to the bottom brim of baseball caps can be helpful in allowing d/Deaf students to see interpreters or lipreading.

Additional support outside the classroom can allow students to get the most out of their astronomy classes. As discussed, d/Deaf students often do not have the same morphological understanding that other students do, thus additional vocabulary instruction through all levels of education has been shown to allow students to be more successful (Trussel et al., 2018). This understanding allows students to be more successful in not only that class, but any future science classes they take.

Keeping the classroom accessible for d/Deaf students is important as interest in topics such as astronomy is often sparked and sustained during school. If astronomy classes are frustrating for d/Deaf students, they are less likely to develop interest and continue into the field, limiting the numbers of d/Deaf people in the subject. Bettering the experience of astronomy for d/Deaf students could increase the number of d/Deaf students in astronomy programs (Nordhaus et al., 2020).

Additional Inaccessible Environments

Other than classrooms, there are inaccessible locations d/Deaf people often face when interacting with astronomy that poses specific challenges, many of which will be covered in this section.

Planetariums. Planetariums are a popular venue for children and adults alike and a common place for people to gain interest in astronomy. However, due to the darkness, audio, and necessity to look up, they can be very inaccessible for d/Deaf people, making them less

educational and enjoyable. Planetarium shows are often not captioned or transcribed. The darkness can make lipreading any presenter or host difficult in addition to difficulty seeing an interpreter. Additionally, needing to look at either of these means the participant must look down from the projected show, missing the visuals important for education and enjoyment. This is significant as it has been shown that people learn less effectively when their attention is split between things with spatial separation (Hintz, et al., 2015).

Many researchers and planetariums are putting in effort to become more accessible to d/Deaf patrons. For example, the Buenos Aires Planetarium renovated in order to install a hearing loop, a system throughout a room that allows sound to be directly received by a hearing aid. Additionally, the planetarium hosts subtitled and interpreter shows for their d/Deaf audiences (Cacace & Pereyra, 2022).

Captioning is a simple way to help make planetarium shows more accessible. However, there are multiple ways to deliver these captions, each with their own pros and cons. Members of the International Planetarium Society (2014) discuss such strategies. The simplest of which involves having captioning on the dome to be seen by all, called open captions. This also eliminates the need to look away from the dome to read captions. Some people, however, dislike it as hearing attendees might find the captioning distracting. There are methods that allow only specific people to see the captioning including individual small captioning devices that are either handheld or connected to the seat, which are common in other types of theaters. Other methods include a captioning system that involves captions to be projected backwards on the wall behind the audience. The d/Deaf person then has a reflective plastic sheet that reflects the captioning into their view. Depending on the shape of the planetarium, however, this might not work. With rising technology, a captioning method becoming increasingly popular is captioning through glasses or other headsets that allow the captioning to be constantly in the viewer's line of sight.

Different d/Deaf people will have different preferences with captioning. It is important to mention, however, that captioning methods that involve additional devices or equipment might have an alienating effect on the d/Deaf attendees, which is why some prefer open captions as there is no difference in experience between all in attendance.

Some prefer interpretation to captioning, especially those who might struggle with technical English. However, the darkness of planetariums makes seeing signs difficult. Additionally, having to look from the dome to the floor might worsen the experience. A simple solution is employed at some planetariums which involves a red spotlight illuminating the ASL interpreter. In addition to interpretation, some planetariums provide scripts of the program (International Planetarium Association, 2014). Like with captioning, some people worry that the light and interpreting will distract audience members or will affect the view of the dome. To solve this, Hintz et al. tested head-mounted displays that allowed d/Deaf users to watch a planetarium show with an ASL interpretation in their line of sight at all times. The study found that students using the headsets successfully viewed, understood, and retained a planetarium show. One student also noted that the headsets had an additional bonus of allowing d/Deaf audience members to sit wherever they please, as most other accommodations such as captioning methods and interpretation require people to sit in predetermined seating. These headsets, however, might have the aforementioned alienating effect, but this will likely be minimized as technology allows these devices to get smaller and smaller. For planetariums, it is good practice to have multiple accommodation options for d/Deaf audience members as everyone will have different preferences.

Observatories. Observatories, popular locations for public, educational, and professional crowds, have similar issues to planetariums regarding the dark and sight lines. Regardless of referred communication methods, whether it be signing, lipreading, writing back and forth, or

transcription, the dark environment causes issues. Because of language barriers, being in the dark can be scary, isolating, frustrating, degrading, and embarrassing according to the account of one deaf woman (Del Pizzo, 2017). For d/Deaf people who utilize residual hearing, the large, echoing space of an observatory, or when observing outside, can cause issues as well. Sounds like wind or other noises common outside make it difficult to catch speech or other noises. Additionally, when observing outside, common hearing devices such as microphones or hearing loops cannot be used. For those who sign, interpreters would be difficult to see in the low light. Additionally, many older or smaller observatories might not have adequate room for an interpreter to be viewed properly.

Steve Majewski, a hearing astronomy professor at the University of Virginia with many years of observational experience, gives some insight to obstacles a d/Deaf observer might face in an observatory. Majewski states that, as many observatories and similar sites are very old, his hearing has alerted him to safety hazards, such as materials falling from the dome. Additionally, he notes that hearing allows him to know when instruments are in use, such as when telescopes are moving, and that they are working correctly with no issues. He notes that if someone moved the telescope, and an observer in the dome was unaware, it might be very dangerous. However, it is important to note that many d/Deaf people are very sensitive to vibrations, and likely would feel the telescope moving.

Some issues, however, cannot be avoided with vibration sensitivities. Majewski notes that a lot of communication in observatories occurs between the control room and the dome via communicators such as walkie talkies, which is not accessible for d/Deaf participants. Dutton (introduced on page 20) notes that there are often difficulties in the dark as she cannot lipread in the dark. Additionally, common transcription equipment does not help preserve night vision. She also notes that in academic settings, such as professional observing with a small time frame,

people are less willing to repeat themselves to d/Deaf observers. While not observing, Radar astronomy might also cause some issues for people using hearing aids. Finally, many astronomical buildings such as observatories and department buildings predate the Americans with Disabilities Act, the ADA, passed in 1990. This means they might not be up to modern accessibility standards.

There are ways to make observatories and other observational environments easier for d/Deaf people to navigate, both regarding outreach events and professional observing. Today, remote observing is becoming more and more popular, so it is easier for d/Deaf people to be on an equal field. However, that does not excuse observatories from becoming accessible. This can be accomplished in various ways. For example, using red spot lights would make visibility of interpreters and lipreading much easier. However, Majewski notes that there are some instances in which red lights are not ideal, such as when instruments sensitive to those wavelengths are being used. Additionally, transcription software that is night-vision friendly, such as using red text, can be used during observations.

Majewski recalled experiences during the COVID-19 pandemic, when observers were required to be in domes alone. Due to the safety concerns of being the lone person in the dome, he says observers were given devices that monitored them for falls or other concerning statuses. He suggested that these could be given to d/Deaf observers to overcome safety concerns anyone might have. He does note, however, that these devices are not perfect and need work to make them more accurate and effective. To overcome other communication and safety concerns, Andres Almeida, a fellow astronomer and peer to Majewski suggests that a light system would be easy to apply in observatories so that a red light comes on when the telescope is in motion. Majewski adds “that would be good for everyone, actually, for safety.”

For outreach events such as public nights, the McDonald Observatory through the University of Texas notes that they offer assistive listening devices, as well as program scripts and sign interpretation for d/Deaf participants.

Conferences and Professional Events. According to Voelker et al. (2022) with SciAccess, networking and social events such as conferences, seminars, and fairs are often inaccessible for d/Deaf people in scientific fields. Not only does this ruin important experiences for these professionals, it also harms employment prospects. Other professional social events such as department dinners are often difficult for d/Deaf individuals to participate in fully (Aarnio et al., 2019). Of course, providing interpreting at professional events is an easy way to provide accessibility, however, deeper consideration is required. At events with simultaneous presentations, hearing attendees are able to move from event to event at their discretion. However, most events only provide interpreters at locations a d/Deaf people confirmed they will be attending, thus d/Deaf people are often tied to the location of the interpreters. This restricts the experience of d/Deaf attendees and denies them equal accessibility. Of course, one fix is to provide an interpreter at every event on a program, however, this is likely too costly for most events. A cheaper solution is to guarantee there is only one event occurring at a time, but this is not probable for larger conferences or events. Another solution that many suggest is instead of assigning interpreters to events, assigning interpreters to d/Deaf patrons. Providing each d/Deaf patron an interpreter allows them to go where they please, as well as having an interpreter in times and spaces between events, so they can participate in the social aspect of these events (Nordhaus, 2019, Aarnio et al., 2019). However, having an interpreter follow them around might make a d/Deaf attendee feel dependent (Nordhaus, 2019). As mentioned, all d/Deaf people will have varying preferences and it is important to keep this in mind when planning events.

In addition to interpretation, many events use transcription or captioning during lectures. Some factors to keep in mind related to this is that CART captioning, that is, captions that are being typed real-time by a person, rather than being auto-generated, are often higher-quality and more accurate than auto-generated captions (Aarnio et al., 2019). Additionally, some d/Deaf people feel that it is helpful for the front seats closest to the presenter to be reserved for them so they can lip read or use live transcription apps that are dependent on audio input more successfully (Nordhaus, 2019).

Outreach Events. Outreach events are important to get the public interested in astronomy and to get children interested in the topic. A common issue of astronomy outreach events, such as Dark Skies Bright Kids, a Charlottesville-based program serving elementary students, is simply that they are not prepared to work with a d/Deaf participant. Whitney Richardson, who is involved with DSBK, stated that the group would not know how to best serve a d/Deaf child if one came to one of their events. Outreach events need more resources and preparation for d/Deaf participants to help build a positive and effective environment.

Financial Considerations

Through writing this thesis, it is not without understanding that a lot of the solutions discussed are very expensive and may not be plausible in all contexts. However, insufficient accommodations due to underfunding should not be made the problem of the d/Deaf people involved. Braun notes that while accommodations can be expensive, this should never be made apparent to d/Deaf students, who might be made to feel unwelcome in their program. Additionally, students might feel pressured to give up necessary accommodations or drop programs. Meredith notes that though very helpful, hiring people to creative astronomy-related videos in ASL is very expensive. However, things must be done to ensure programs and events have the funding required to create a positive and effective environment for d/Deaf participants.

Dr. Marius Eide, a Deaf Norwegian astrophysicist, notes that his ability to enter astronomy was made possible because the costs of interpreters was covered by the Norwegian government. He states that had they not covered the cost of his accommodations, he would have been forced to pursue a different field (United Nations…, 2021).

Conclusion

Further research needs to be done to determine the specific efficacy of the solutions discussed throughout the thesis. However, this, hopefully, starts the important conversation of how to minimize the barriers keeping d/Deaf people from astronomy and increases the number of d/Deaf people involved in astronomy across the hobby, educational, and professional contexts, allowing an important scientific field to stay accessible to an under-considered population. Tackling these barriers is important in order to best serve a widely misunderstood community. Additionally, any work to make astronomy more accessible for d/Deaf involvement is important due to the interconnectedness of the factors discussed in this project. For example, simple efforts in making a classroom more accessible has the potential to ripple into great effects. Perhaps one d/Deaf student in the improved classroom goes on to become a faculty at a university. This role model could lead other d/Deaf students to become involved, and so on. Any effort toward making astronomy more obtainable for d/Deaf participation allows the field to head toward a more accessible and equal tomorrow.

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