DEAF STUDENTS – A REVIEW OF BEST PRACTICES AND CRIPPING THE STEM FIELDS

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Introduction

As written by Lodi (2013) and cited in Snoddon & Murray (2019):

"…deaf students can do nothing but adapt to the teaching methodologies designed for hearing students; and interpreters can do nothing but be responsible for the process of teaching-learning content, without any consideration of the training of these professionals, of the stage of language development of deaf children [learners, author's emphasis] and the importance of the teacher-students relationship for school teaching and learning.".

As this quotation has clearly described, it is not just about providing American Sign Language (ASL) interpreters to do the interpretation of English to ASL as a communication modality for deaf students, a human right achieved in Canada by Howard (1993). Indeed, still more work is needed to make the teaching and learning of deaf learners in educational spaces more effective, as emphasized in Lang (2002).

Furthermore, this history of deaf education also has an impact on interpretation processes (Knox, 2006) as follows:

- Poor quality of education prior to post secondary education
- ASL interpreters are in short supply
- Notetakers that are skilled are in short supply
- Awareness of deaf culture once deaf student(s) enter a post secondary institution
- Lack of knowledge identified in the needs and skills of deaf students by accessibility experts
- Discourse commonly seen in the academy can be challenging to follow
- Interaction with other students who are nonsigners are not often meaningful.

Moreover, from an employment perspective, coming out of a large European research project (DESIGNS) the employment pathways were examined for deaf signers (Napier et al 2020). One key theme coming from the pathways normal in employment (1:1 meetings, group meetings, progression, conflict and social settings) was the training needs for deaf signers, employers and interpreters. This theme was identified with gaps shown in knowledge and experience.

While taking educational studies, deaf signers were found to require support in the transition to the workplace. This process of transition was recommended to have discourse in how to work in hearing dominant settings, what are the expectations, cultural norms customs and practice of a common hearing workplace. Work-related supports available (via the duty to accommodate in the Canadian perspective) need to be made aware to Deaf students, and what is required to do to access those supports. Context regarding interpreters in the workplace settings is to be discussed with a deep understanding how the interpretation process means for a deaf individual being represented and perceived by others and what this means for your work career. Practical training in workplace settings with interpretation will help deaf students understand what is involved, with a recommendation those settings be recorded for reflective learning. At the time same, this will be of benefit to involved interpreters to obtain feedback and do

reflective learning as well. It is recommended that internship programmes and mentoring is to be set up if not yet available to recently graduated students while transitioning to the workplace (Napier et al 2020).

Deaf students need to acquire and have experience in work related activities, including interviews with interpretation. This allows practice in negotiating how to do self-representation through interpreting, how to provide context that they are identifying as a deaf person and how to discuss this context. Moreover, internships were identified as one way to bridge the experience gap of deaf students and this is imperative to be done in the early stages of one's career. The internships offered needs to also come with opportunities to identify mentors who are senior experienced employees and are willing to give guidance to deaf students (Napier et al 2020).

This best practices document aims to review the literature of recent research that shows what works and more importantly what is not for deaf learners and students. The scope has been narrowed down to the STEM fields in the laboratory and classroom or lecture as well as to discuss proposed solutions to fill in the gaps as identified in the DESIGNS project, funded through the Erasmus+ programme.

In the laboratory working with Deaf students

As Pagano has stated in Smith et al (2016), concerns about laboratory work and safety for deaf scientists are typically attitudinal in nature, consistent to what is stated in Seal et al (2002) – approximately a decade interval of those two journal articles with little change in attitudes reported. This can be seen from experiences in laboratories which are often commented to be isolating from the perspective of deaf students (Gehret, et al, 2023; Majocha et al, 2018). The experience of isolation is thought to be mainly due the existing communication mismatch or behaviours due to lab environments not incorporating deaf culture competency or awareness, ensuring self-advocacy, and deaf mentor availability.

It has been shown that just doing laboratory classes in post secondary scholarship is insufficient to embracing one's science identity. However, this type of learning does induce positive attitudes towards science in general (Gromally & Marchut, 2017; Marchut & Gromally, 2019). Regardless doing laboratory work or "inquiry based" learning is not sufficient to one's identity despite this being a strong belief by science faculty this is sufficient for a long time since Wihelm von Humboldt suggested learning through inquiry in 1810 (Seal et al 2002; Smith et al 2016). This has and in addition to other factors have amplified negative impacts on obtaining one's science-identity, attitudes, interests and careers.

Strategies to ensure the experience of isolation does not occur would include:

- Full communication access
- Developing a knowledge of deaf culture
- Teaching self-advocacy
- Have mentoring available

Gehret et al (2023) has verified those strategies to be relevant for deaf students across multiple laboratory environments, who value the benefits of sign language and interpreting and perceived to be the most effective strategies. This is reflected in the utilization of ASL interpreters working part-time when deaf students are hired to participate in research activities in the summer term (Seal et al, 2002). The work occurred in the laboratory, morning lectures, discussions (both formal and informal) and presentations along with hearing students and a professor. The part-time interpreter also worked with interpreting students who interpreted informal conversations as part of their school curriculum (educational interpreting).

Students who have self-advocacy often ask for deaf awareness workshops to be provided to their laboratory colleagues and this is to be asked of the post-secondary institution to organize (Gehret et al 2023; Pagano et al 2015; Smith et al 2016). In addition, mentors (typically advisors or principal investigators) can also do advocacy for deaf students (Majocha et al, 2018). This is consistent to what was recommended in Listman and Dingus-Easton (2018) in that hearing mentors provide appropriate and of quality access services to support the learning of deaf students in the laboratory environment. As well, in employment whether in summer terms or internships it is often the hearing co-workers or supervisors are more concerned about how to communicate while the deaf student employee less so (Smith et al, 2016). This is in the sense of supporting such students in circumstances where deaf awareness is lacking, or limited communication was occurring due to extraneous factors, as seen as well in the classroom (Hendry et al, 2021 – see the "in the classroom, Deaf student learning" section for further details).

In most cases the mentoring given by advisors or principal investigators were found to be a positive attribute to the laboratory environment. Of note advisors or principal investigators did not value any proposed strategy, indicating lack of awareness of deaf culture or the interpreting process, so resources in those two areas should be provided in advance (Gehret et al, 2023). Even a small base knowledge of signs has been found to be effective in strengthening relationships and improve communication, recommending that faculty mentors (advisors, principal investigators) take ASL classes (whether online or in person) (Pagano et al 2015, Smith et al 2016).

Braun et al (2017) has identified factors in mentoring deaf students while designing a mentoring survey. From this work, it was discovered that good mentors provide encouragement and need to have cultural awareness and know about communication barriers in depth. This is consistent in Lynn et al (2020) where mentors need to have essential comprehension in cross-cultural dynamics. Intersections of norms between hearing and deaf individuals can lead to discussions in finding strengths and what to improve in the laboratory environment. Moreover, encouragement to tap in the local deaf community as connections to self-advocacy skills, networking, what resources are available are encouraged for deaf students to utilize by mentors (Braun et al 2017). As long as the mentor faithfully knows deaf culture, this then becomes a non-issue if the mentor has hearing status or is deaf (Braun et al 2017). So resources of deaf culture awareness should be made available or is to be accessed for learning, consistent to what is stated in Pagano et al (2015), Smith et al (2016) and Lynn et al (2020).

Changing how advisors train was found to be emphasized as the traditional way of training by demonstrating and verbalizing at the same time is ineffective for deaf students who prefer visual attention (Gehret et al 2017; Smith et al 2016; Seal et al 2002). As visual acuity is reduced if need to focus on multiple features. One solution to this ineffective traditional practice due to the communication mismatch is to give preparatory materials ahead of time before the demonstration or training (Gehret et al 2017, Smith et al 2016). During the demonstration or training more focus can then be done with the technical nuances commonly seen in experiments (Gehret et al 2017). Additionally, creating or recording video of tutorials or training with an ASL interpreter's presence allows the deaf student to learn the techniques at their own pace, by replaying sections as required (this author's personal experience; Gehret et al 2017).

Gehret et al (2017) described the most common challenge in research experiences by deaf students is the missed information during technical discussions, as well as social topics when discussing with advisors or peers in the laboratory. This is typically known as soft skills including relationship standards, email/meeting etiquette, conflict resolution approaches, or navigating workplace politics (Lynn et al 2020). This is clearly much more accessible to hearing individuals but not so for deaf students, as this knowledge of sociocultural norms of majority hearing populations existing in academic environments is not written down or clearly communicated. This "informal curriculum" or "incidental learning" can be

evaluated by the assigned mentor to the deaf student, by filling in gaps in the sociocultural knowledge of the deaf student, as long the mentor has deaf awareness knowledge, as this "cultural reference" in navigating the academy can be done by sharing stories of tales and triumphs (Lynn et al 2020).

When having deaf students in the laboratory, high importance was given to ensuring a cohort of such students should be common practice. That is the deaf student worker should have at minimum a deaf colleague or mentor present, as a proposed solution of the experience of isolation commonly reported (Majocha et al 2018; Pagano et al 2015). In addition, it was advisable to establish an online mentoring resource where deaf students are connected online to discuss research experiences.

If peer mentors are utilized by advisors or principal investigators emphasis was made to make sure such peer mentors are expected to have additional time working with a deaf student and most importantly to practice patience (Gehret et al 2017). This is especially important seeing that laboratory mentoring take place *ad hoc*, with no planning ahead (Pagano et al 2015). As well, this allows for a "buddy" system where students are working in the laboratory as pairs, especially working with known hazardous materials or on overtime (Smith et al 2016).

In the classroom, Deaf student learning

In a study of deaf Scottish students, Hendry et al (2021) found that university staff and peer students was lacking in deaf awareness which made the learning environment interactions exclude the deaf students. It was suggested that in delivering course content and adapt information to be accessible with supports should start with deaf awareness workshops at an institutional level, rather than at a personal level. This is also consistent with deaf students attending post secondary institutions in New Zealand have had expressed frustration about limited knowledge and techniques in communicating of staff in such institutions (Powell et al 2014). As deaf students have mentioned as information is always missed in classes, scheduled support meetings with lecturers and tutors should be done to ensure information provided is not overlooked. The underlying context to those learning interactions may be the unclear continuum of responsibilities that reside in faculty and students as observed in Foster et al (1999).

In particular, lecturers were found to have two characteristics that were valued by Norwegian deaf graduate students (Kermit & Holiman, 2018). Those characteristics are understanding deaf people and being able to communicate in sign language. A systematic view of the lecture room was described in such placing deaf students within a classroom may seem inclusive (even with a sign language interpreter or a lecturer who signs) however students are forced to be individually responsible for their learning needs. Rather this is a placement type of framework instead of being inclusive, in doing so academic learning by deaf students take so much priority that other needs including social interactions (i.e. with hearing peers) were being neglected due to lack of time and energy (Kermit & Holiman, 2018). Taking this frame indicates that the post secondary institution needs to place inclusion rather than placement as an obligatory practice by all staff members. So lecturers need to have an attitude that is open and receptive of deaf students, of their needs and preferences and adapt the lectures in return. This requires intercultural competence of attitudes, knowledge and skills in communication. This is consistent in Ross and Yerrick (2015) where a professor approached two deaf graduate students as a "breaking the ice" to what needs they would appreciate beyond the accommodations provided (i.e. ASL interpreting and CART). This allowed the deaf students to introduce the concepts of cultural sensitivity or etiquette (i.e. to look at the deaf student, not the ASL interpreter), how to moderate discussions (one person speaks one at a time) and so on.

Another aspect that is common in scientific workplaces or classrooms is the face-to-face debate with peers, with such debate taking place as overlapping talk, quick turns, detours, discussing hypothetical

statements (Ross & Yerrick, 2015). This type of debate does exclude deaf individuals as information including visual cues of peers are missed due to the need of paying attention to the interpretation, of which the involved interpreters have commonly not prepared for, so the solution to this is to explore alternative ways of communication. Furthermore, this lack of awareness from the hearing participants in dialogue or discourse, for example there is typically a hint to one's end of verbal discourse and combined with the delay in interpretation leads to responses from other participants rather than not waiting for the interpretation to complete then give everyone an equal opportunity to provide a response. A suggested solution to this was to raise your hand and let the chair of the meeting take note who wishes to reply (Ross & Yerrick, 2015).

Ross & Yerrick (2015) has commented that techniques used to introduce new tools to deaf students often require some thought to how those techniques are to be utilized, so the proper balance of the techniques require deaf students' feedback. Dilemmas like this for lecturers often don't have guidance resources, although it is a common strategy to group deaf students together which may not be ideal as this limits interactions with other peers and access to knowledge available in such peers (Ross & Yerrick, 2015). Rather it is still best practice to ask the deaf students their preference given the circumstances (Ross & Yerrick 2015). This is consistent to Mousley and Kelly (1999) where student involvement in solving problems in mathematics by repetitive practice, active participation, discussion that is interactive and feedback being evaluated for internalization of new skills and knowledge.

As well, alternative communication methods of course content need to be considered in discussions with or learning by deaf students as English is commonly a second language of such students so engagement with learning and social interactions are both impacted. That is, to be in British Sign Language (BSL), not just in English either written or spoken, in videos, written application forms asking for details that could be provided in BSL. It has been found that engagement of deaf students improves if the learning course content or interactions with hearing students were designed to be approached in multiple ways, not just in written or spoken English (Hendry et al 2021). This is consistent with the preferred use of videos in Malay sign language (MSL, in Malaysia) out of multiple features offered in an online environment when accessing context to learn. This was found to be correlated with better outcomes of learning (Hashim & Tasir, 2020). Furthermore, Stinson et al (2009) reported that no significant difference was seen in retaining information by college students using either CART or ASL interpretation. This was noted with reading proficiency being important to retained information from lectures. The interpretation approach also would depend on students' preference in learning in the classroom based on the complexity and demands of the topics under discourse (Napier & Baker, 2004) – implying the importance of multiple ways of communication.

With utilization of group work in more use those days, Marchetti et al (2012) examined the possibility of using white board on classroom walls or tablet PCs to facilitate communication between deaf, hard of hearing and hearing students. The scope of group work as a possible area of further exploration of communication with the class context of introductory statistics and a small number of participants (under 10) and short intervention length, so no learning outcome assessment was done. Similarly, this was suggested in Smith et al (2016) with the use of individual white boards, notepad apps, instant messaging on smartphones in the laboratory. Of interest in what is reported in Marchetti et al (2012) was that communication using white board or tablet PCs did not always help communicate or understand the materials as reported by the participants.

Asking for accommodation (the duty to accommodation)

Bruan et al (2017) has empathized that mentors need to support deaf students when asking for accommodation. In giving such support, mentors familiarizing with how systems of accommodation works in one's institution is absolutely essential (Lynn et al 2020). Communication in the laboratory should be one of the first discussions between the mentor and deaf student(s), to ask for individual preferences (Bruan et al 2017). Note that decisions on preferences may not always be promptly done when new to the laboratory or classroom, as often being present in the research environment allows a deaf student to determine the best solutions to communication barriers then preferences can then be stated (Lynn et al 2020). This is consistent in Listman & Dingus-Eason (2018) as effective mentorship and advocacy where hearing mentors reach out to institutional disability services office (currently more commonly known as accessibility services) and ensure the deaf student(s) get appropriate accommodations (ASL interpreters, et cetera). This is meant to mitigate the culture and language barriers in the laboratory environment.

The access of interpretation needs to be funded for social engagements and functions, not just for academic learning work (Hendry et al 2021; Stinson & Walter 1997). This is a solution to the documented poor engagement with other hearing students using written or spoken English or attending non-academic events hosted by the post-secondary institution including open day, career networking, counselling, interviews and so on. Not including extracurricular activities in the university environment can have an emotional impact on deaf students due to the lack of meeting new people and establishing a network of contacts for future potential work opportunities. As those activities are agreed to be part of student life which can lead to deaf students to be susceptible to being isolated, loneliness and experience social exclusion as poor mental health outcomes. This was also observed in New Zealand post secondary institutions where deaf students expressed dissatisfaction in social (and academic) interactions, especially with peers with emotions of rejection, loneliness and isolation reported, implying this theme is consistently present from country to country (Powell et al 2014). Brown & Foster (1991) has noted that friendships between hearing and deaf students usually don't emerge from the classroom, rather it is the perceptions of hearing students in social interactions that occur on campus that determine success in the social domain. So, the utilization of interpretation is essential in all aspects of academic activities, not just the classroom, but for extracurricular activities (Hendry et al 2021).

An additional layer of complexity to the utilization of ASL interpreters is the lack of qualifications to be doing the interpretation in post secondary classes which indicates lack of screening of such qualifications before being hired (Hendry et al 2021). This can be seen in the linguistic language used in scientific fields which often have no corresponding sign in ASL (Lynn et al 2020). One solution suggested was mentors taking the time to support this necessary interpretation of technical jargon with deaf students and interpreters as this will improve the quality of communication, additionally allows a friendly introduction to the laboratory culture.

Disseminating research findings at conferences

Years ago, poster sessions were introduced at meetings of the American Chemical Society, this being attributed to the presence of a deaf scientist (named Nancie Sharpless), indicating a deaf gain perspective in disseminating information at conferences (Pagano et al, 2015; Bauman & Murray, 2014). If students are asked by advisors or principal investigators to present at conferences, then it is imperative that the communication mismatch is to be managed.

Typically, ASL interpreters or CART specialists are booked by the conference organizers upon request by the deaf student (Smith et al, 2016). However, typical common knowledge is that such ASL interpreters do not have a scientific background, so the use of technical jargon can cumbersome the interpretation

process (Pagano et al 2015). Again, the poster or presentation material is to be given ahead of time to the booked interpreters as preparatory material. Alternatively, it is advisable to meet with the interpreters at the conference before the session to discuss the context in depth. Lastly, the interpretation process should be understood by all participants that complete accuracy is not the expected norm and is due the lack of familiarity of technical jargon during the process of interpreting (Smith et al, 2016).

Kasper et al (2024) has recommended checklists for receiving requests of accommodations from Deaf individuals registering in conferences. To ensure that experiences for deaf students (and professionals) are consistent from conference to conference or even attending the same conference year to year, it was suggested that standard operating procedures be adopted by conference organizers in the STEM fields with the recommended checklists as a starting point.

Deaf scientist representation in the classroom or lecture

In introductory science courses, it is often seen in the course textbook with explanations of key discoveries in the field of work as part of scientific history. Still today, it is still uncommon to mention the valuable contributions of deaf scientists. If a deaf student is registered into a course, it is useful that the instructor or teacher of the course to identify such Deaf scientists and include in the curriculum (Braun et al 2017). This comes from the concept of "Deaf can" which is a translated ASL phrase often framed from Deaf lens or knowing gains can come from being Deaf (Smith & Andrews 2015; Kruz et al 2016).

The first step would be to contact a Deaf scientist for suggestions and refer to the list of known earned doctoral degrees of Deaf individuals in Canada, United States and internationally (No author, tinyurl.com/deaf-docs). Referring to this list, it is then important to consider the student's background and interest to select Deaf scientists of relevance (the intersectionality aspect).

As an example, one Deaf scientist contributing to the field of chemistry (this author's field of work) is George T. Dougherty, who completed school work in applied and analytical chemistry then did work in metallurgy (Deaf-Mutes' Journal, 1934). In particular, a focus was in quantifying vanadium in steel used in train axles, as a method to delay train axles from cracking. As well a video of Dr. Dougherty could be presented in the classroom as an example of a Deaf scientist describing chloroform, a chemical compound (Supalla, hsldb.georgetown.edu/films). Those two aspects to Dougherty's work give an illustration to scientific work, from a deaf lens.

In another example, the process of inventing the television apparatus was done by multiple individuals including a deaf scientist named Wladislav Zeitlin (born 1907), with a background in physics and engineering (electricity). Zeitlin held patents from multiple countries including England, France and Germany (Zarurov, 2014). This driven work by Zeitlin was due to the deaf gain vision to make communication (broadcasting) visual. This technology advancement has led to the video phone which is now common in everyday use by everyone. This could be demonstrated in the classroom as an introduction to the concept of deaf gain (Bauman & Murray 2014).

Along with name sharing with deaf students, it is imperative to draw on physical materials in the classroom, laboratory or the workplace showing the history of Deaf science. One example could be the field of astronomy that has overlooked contributions from Deaf scientists, including Annie Jump Cannon, John Goodrick, Olaf Hassel, Robert Aitken, Konstantin Tsiolkovsky, Henrietta Swan Leavitt. Posters as offered by a Deaf led non-profit (Atomic Hands, 2024) can be purchased to learn the stories of those six scientists doing astronomy research – six posters to be put on the walls of the classroom, workplace or laboratory.

Benefits when working with deaf students

Academic success of students were noted in Convertino et al (2009) to be mainly predicted by being prepared beforehand with knowledge of the information, skills of learning and have communication flexibility (i.e. to know multiple ways of communication). In the United States, this is reinforced by National Science Foundation's Research Experiences for Undergraduates (REU) programming having slots available for deaf students, so the principial investigators involved in those programs become knowledgeable and act as advocate for deaf students (Braun et al, 2017)

In understanding and identifying barriers typically experienced by deaf students this has led to positive outcomes including presented scientific work at conferences or written in scientific journals in support of the hosting laboratory and the resulting research work gives the deaf student a sense of pride in those accomplishments (Smith et al 2016). As well, the cultural awareness that comes out of taking ASL classes or awareness workshops lead to better understanding, allowing unique experiences impact scientific research (Smith et al 2016). This is supported in Jambor & Elliot (2005) where self-esteem had a strong association with bi-cultural skills, implying that higher self-esteem means success both in Deaf and hearing worlds.

From an economic perspective, graduation from post secondary institutions have demonstrated monetary benefits for students as compared to those who do not complete a degree (Schley et al 2011). This indicates persisting to a degree is critical as no significant difference was observed for students who did not get a degree and those who never went to post secondary. Note that this interpretation was derived from data of student enrollment at National Technical Institution of the Deaf (NTID), one of the colleges at Rochester Institute of Technology.

Finally referring to Henner and Robinson (2023), how do we crip the STEM fields in Canada? One would necessarily need to change the academic institution (the system) to promote language diversity as a valued and vital aspect of society however is found to be encountered with resistance (Lynn et al 2020). Rather, faculty as mentors, accomplices or advisors should leverage the popularity of learning ASL taught by deaf faculty through courses available in person or online (contact the author for further information) (Robinson & Henner, 2018). The profits earned from such courses could be directed to supporting deaf students in the academic environment, to resources of deaf awareness, self-advocacy and mentoring as this review has identified as essential to the success of deaf students as scientists. Ultimately, due to the complexity in teaching and promoting learning of deaf students, one realizes a more simple solution is to mimic the systems in place at Gallaudet University or NTID (both in Eastern United States), so it is time for Canada to have its own Gallaudet.

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