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EDITED BY

Jessica Norberto Rocha,
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Henry J. Adler,
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Universidade Federal do Rio Grande do Sul,
Brazil
Kim Kurz,
Rochester Institute of Technology (RIT),
United States

*CORRESPONDENCE

Joseph A. Harsh
✉ harshja@jmu.edu

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An assessment of an intentionally designed US summer research program that integrates Deaf, hearing, and sign language interpreting students in chemical research

Joseph A. Harsh^{1*}, Chrisi A. Hughey², Isaiah Sumner²,
Nathan T. Wright², Isobel Cobb¹, Frances Thiry¹,
Anneliese Rogerson¹, Emma McGehee¹, Ashlynn Stacy¹,
Savannah Sprouse¹ and Trinity Dovan¹

¹Department of Biology, James Madison University, Harrisonburg, VA, United States, ²Department of Chemistry and Biochemistry, James Madison University, Harrisonburg, VA, United States

Participation in undergraduate research experiences have been shown to positively influence the learning, development, and educational and career trajectory of students, particularly for individuals from groups traditionally excluded from science, technology, engineering, and mathematics (STEM) fields. As few studies have explored the engagement of deaf and hard-of-hearing (DHH) researchers in inclusive laboratory experiences, this article reports on the assessment of a long-standing summer program that draws on best practices to integrate DHH, hearing, and sign language interpreting students in chemical research. To assess outcomes associated with participation, mixed survey data were collected from student researchers over three consecutive program years. Findings highlight the positive impact of the program for all participants, particularly how the experience contributed to hearing students' awareness of Deaf culture and inclusive communication strategies. While this case study highlights a model for a unique student group, the general lessons learned are broadly applicable to creating inclusive laboratory environments for researchers of varying abilities and how participation in such experiences may benefit mainstream students' cultural competences as future practitioners in science disciplines.

KEYWORDS

Deaf and hard of hearing (D/HH) students, Deaf and hard of hearing (D/HH) researchers, undergraduate research, inclusive laboratory, student research, cultural competency and awareness

1 Introduction

Undergraduate research experiences (UREs) that afford students research opportunities to “do science” have long been identified as a key strategy in preparing the next generation of scientists and broadening participation in science, technology, engineering, and mathematics (STEM) fields ([National Academies of Sciences, Engineering, and Medicine, 2017](#)). Participation in UREs benefit student learning and persistence, particularly for individuals from groups traditionally underrepresented in science fields by ethnicity/race, gender, socioeconomic standing, and/or abilities ([Laursen et al., 2010](#)). In addition, as scientists are shaped by their unique life experiences and bring these perspectives to their

research (Braun et al., 2017, 2018), UREs that engage students with “disabilities” have the potential to advance mainstream participants’ cultural competencies and benefit the quality of science broadly (Gin et al., 2022; Gormally, 2017; Gormally and Marchut, 2017). Yet, despite this, and the lacking representation of deaf/hard-of-hearing (hereafter DHH) scholars in advanced STEM degrees and workforce (National Center for Science and Engineering Stats 2023, 2023), little work has been undertaken on URE programs intentionally designed to offset barriers in the laboratory environment for DHH students and the benefits conferred to their hearing counterparts. To address this gap, we report here on a program designed to inclusively engage DHH students in scientific research and how the experience impacts hearing students’ awareness of the Deaf community.

DHH learners of all ages often encounter unique systematic barriers within formal and informal learning environments when engaging in scientific inquiry (Ferreira et al., 2023; García-Terceño et al., 2023; Gormally and Marchut, 2017). Compounding communication and environmental challenges (e.g., auditory dominant procedures) as well as perpetuated ableism in educational settings may exclude or limit the full participation of DHH learners in inquiry activities (Lynn et al., 2020). In undergraduate research, DHH students commonly encounter day-to-day barriers relating to communication accessibility (i.e., access to research-related information and resources) and inclusion (Braun et al., 2017; Marchut, 2017; Majocha et al., 2018). The physical constraints of laboratory spaces (e.g., layout, equipment loudness) and interpreter availability can limit general communication strategies (e.g., visual cues, audio-to-text technologies) and those specific to DHH students’ preference to speak in sign or English (Listman et al., 2024). Further complicating communication access for DHH student researchers that primarily sign is the nationwide shortage of ASL-interpreters in higher education and industry, particularly those with sufficient training to effectively communicate the technical nature and jargon of disciplinary research (e.g., Ott et al., 2020; Majocha, 2023). Relating to issues of inclusion, as mentors and lab members are often unaware of Deaf culture, unintentional actions often result in DHH student researchers feeling a lack of welcomeness or sense of belonging—a key psychological factor for STEM persistence (Hurtado and Carter, 1997)—in the laboratory or field (Majocha et al., 2018; Braun et al., 2018). Such obstacles are further exacerbated by a scarcity of “disability”²-related research, including deafness, in STEM education literature (Chrin and Nardo, 2025; Goodwin et al., 2024; García-Terceño et al., 2023).

In this article, we describe a long-standing summer research model at our institution that integrates DHH, hearing, and sign language interpreting students in chemical research. Our designed framework is consistent with best practices for supporting DHH

student researchers, training ASL interpreters in science communication, and building the cultural awareness of hearing faculty and students (e.g., Braun et al., 2018; Majocha, 2023). While this description highlights a model for our unique student group, the program architecture and its broad impact on participants, is applicable to the creation of inclusive research experiences that engage students of varying abilities. Specifically, this case study provides a blueprint of how participation in diversity-focused programs can contribute to mainstream students’ cultural competences—the ability to engage knowledgeably and respectfully with others across cultures—as future practitioners in STEM fields.

2 Methods

2.1 Program history and overview

The Chemistry & Biochemistry Department at James Madison University (JMU) has provided research experiences for DHH students since 1998 through internal and external funding [NSF Research Experience for Undergraduates (REU)³] funding. An account of our program’s first 20 years can be found in MacDonald et al. (2018). The design and implementation of the program align with inclusive practices outlined in the literature for supporting DHH and “disabled” students in STEM environments (e.g., Braun et al., 2017; Gehret et al., 2017; Gin et al., 2022; Listman et al., 2024) as well as lessons learned in working with Deaf researchers over time in our department. The major components of the program are fourfold:

- *Inclusive Communication Strategies in the Research Setting*

o Access to professional and cultural capital as well as emotional support via effective interpersonal interactions is vital to promoting DHH participant success in UREs (Lynn et al., 2020). In recognition of DHH students’ varied language preferences, our program seeks to offset immediate communication barriers through the presence of interpreters in research and social spaces for ASL-speakers as well as verbal cuing and assistive technologies (e.g., real-time captioning) for those that prefer/use written or oral English (Listman et al., 2024). More broadly, we seek to address systematic barriers by increasing the number of STEM-fluent ASL interpreting undergraduates through apprenticeship-like training in research and social settings by professional interpreters.

- *Engaging Deaf Mentors*

o The benefits of mentors for students that either share nonmainstream cultural backgrounds or navigate cross-cultural dynamics is clear (Lynn et al., 2020; National

1 Per recommendations of the National Association for the Deaf (NAD), the use of capital “D” here signifies the culture and identity of the Deaf community, whereas lower case “d” refers to the audiological conditions of hearing loss or deafness.

2 The use of quotes is to reflect that many DHH individuals do not consider deafness a disability (Lane, 2002), but it is typically classified this way in demographic studies.

3 NSF REU Awards (2015–2026): CHE-9000748, CHE-9300261, CHE-9731912, CHE-0097448, CHE- 0353807, CHE-0754521, CHE- 1062629, CHE-1461175, CHE-1757874, and CHE-21500091.

Academies of Sciences, Engineering, and Medicine, 2017). Each year, the program hosts a Deaf faculty member from another institution that serves as a research mentor for hearing and DHH participants. Such collaboration benefits current program participants as well as promoting continued interactions between students and faculty at JMU and an institution for DHH and signing students during the academic year.

- *Continuous Professional Development*

- o In light of our long history with DHH scientists, as well as those from other nonmainstream groups, department culture and ongoing professional activities contribute to the development of faculty self-awareness and empathy (Dewsbury and Brame, 2019). All program faculty have training and/or experience in creating positive, accessible research environments by facilitating effective communication between DHH and hearing participants and offsetting environmental barriers (Listman et al., 2024) as well as a strong willingness to learn about Deaf culture and ASL.

- *Promoting Cross-Cultural Interactions*

- o A major program focus is community building between DHH and hearing students. Through formal and informal research-related and social activities, we seek to create a program climate that positively contributes to all participants' sociopsychological states (sense of belonging, science identity) as well as hearing students' awareness of Deaf culture (Braun et al., 2017; Majocha et al., 2018).

2.2 Program participants

Our program engages externally funded (NSF REU) participants—including DHH students—and JMU students supported by the department, college, and other grants in 10-week faculty mentored summer research projects. Faculty who mentor student researchers represent all major subdisciplines of chemistry, with expertise in synthesis, biophysical chemistry, and materials. This diversity in research is especially important as DHH students often enter the program with varying interests and backgrounds.

Following program design changes in 2021, 202 students have participated in the summer program over the past 4 years. Approximately 20% of student researchers are externally funded NSF REU participants, including three to four DHH students per year, selected from other institutions through a competitive application process. Almost all REU-supported students come from the U.S. and Puerto Rico and enrolled at predominately undergraduate institutions (PUIs) with 2- and 4-year programs. Hearing, non-JMU students often identify interest in the program in part due to the inclusion of DHH students (e.g., prior ASL experience, personal connections). Two externally supported ASL student interpreters are also competitively selected each year. These students become part of a larger research community with ~40–50 JMU students of varying backgrounds and interests.

2.3 Complementing student activities

In alignment with recommendations for supporting total student growth and development through UREs (National Academies of Sciences, Engineering, and Medicine, 2017), a set of activities are implemented to promote essential research-related skills (communication), community awareness, and science affect (e.g., sense of belonging) to complement laboratory activities. While these events were originally designed to be part of the REU program, all summer chemistry student researchers are encouraged to participate for their benefit. Targeted areas of growth and how they are supported are briefly discussed here.

2.3.1 Effective science communication

Students attend weekly workshops run by faculty from the program or JMU's School of Media Arts and Design. The workshops focus on oral and visual science communication techniques, including introductions and elevator pitches; data visualization (e.g., non-contextual images, design elements), ACS "Talking Science" seminar (ACS, n.d.), and professional networking. Students begin the summer by giving a 2-min presentation describing their research project. Subsequent workshops revise and build upon this presentation to better communicate the "why" and the scientific results to peers (DHH and hearing; other disciplines) and the public throughout later events. This 'science communication' theme culminates in an end-of-summer research symposium, which is organized as a professional conference with keynote speakers and sessions. All workshops and symposia are accessible to DHH students by using ASL interpreters, real-time captioning on personal devices, and Deaf learning space configurations. Layered on this emphasis in scientific communication are weekly sign lunches and other technical workshops (e.g., R, python scripting) facilitated by JMU chemistry faculty. Individual labs are also encouraged to host weekly meetings and journal clubs where students can practice skills learned at these program-wide events.

2.3.2 Developing cultural awareness

Through interactions in research and social settings, focus is placed on helping hearing participants develop cultural awareness of the Deaf community as well as an appreciation for how appropriate accommodations can mitigate barriers. Weekly "sign lunches" led by DHH students and/or ASL interpreters are open to all students and faculty. During these lunches introductory ASL is taught and Deaf culture discussed. From 2022 to 2024, ~80% of summer research participants—including DHH students—attended at least one sign lunch. These students attended 5.5 lunches (of 8) on average. DHH and hearing students also interacted, often with interpretive support, in research and social settings. Students also learn the importance of visual communication as well as speaking clearly and at a natural pace so that ASL interpreters and real-time captioning devices can accurately interpret.

2.3.3 Community building

Program-level social activities are held throughout the summer to build community, including a potluck and ice cream socials with other JMU STEM summer student researchers, a bake-off, bowling, an evening at the JMU planetarium, a trip to Washington DC, and movie nights. Students also organize their own social events around personal interests such as hiking, food (eating out, trips to the farmers market),

and gaming amongst others. As DHH students are distributed across several labs, hearing and DHH students often form friendships and engage in outside activities that rely on various intrapersonal communication strategies—most commonly by text or voice-to-text. Student interpreters may choose to join; however, they are not required to join or expected to interpret if they do. The program recognizes the need for rest and the common incidence of interpreter burnout (Palmer et al., 2025), which the professional ASL interpreters discuss with the ASL interns as part of their mentoring.

2.4 Mentor training

As our department is undergraduate only, all faculty mentors are experienced mentoring student researchers. Continued engagement in professional development opportunities helps train mentors to successfully guide students and effectively foster inclusive research environments in STEM fields (National Academies of Sciences, Engineering, and Medicine, 2019). Faculty mentors attend a workshop prior to the start of the experience to discuss the program expectations, program structure, and challenges associated with mentoring DHH students using the “Working Together; Deaf and Hearing People” materials developed by Rochester Institute of Technology (2025) focusing on effective communication, Deaf culture, and accommodation and inclusion in the workplace.

2.5 DHH communication needs

To ensure an inclusive environment, effective communication systems based on DHH learners’ language preferences—sign, oral, written—are necessary to ensure full access and participation (Ferreira et al., 2023; Lynn et al., 2020). We respect each students’ preferred mode of communication with dialogues occurring between mentors, students, and our Office of Disability Services to ensure we facilitate the most effective interactions. General practices for offsetting communication barriers in the laboratory include the modeling of research procedures, physical positioning, using non-verbal cues and visuals, writing information, and other common strategies (e.g., getting attention first, speaking clearly and naturally; Lynn et al., 2020; Listman et al., 2024). Assistive technologies (captioning, talk-to-text) and reduced noise environments for meetings are also available. For ASL-speaking students, our program embeds a team of interpreters into research groups; commonly considered a “gold standard” and preference for many DHH science practitioners (Ott et al., 2020). A perennial challenge to such an approach is the recruitment of ASL interpreters that are comfortable in the laboratory setting communicating scientific methods and jargon. Here, the involvement of ASL-interpreting undergraduates has been a successful way in both offsetting communication barriers for DHH scholars and training future professional scientific interpreters (see MacDonald et al., 2018 for a detailed account). Recent student interpreters have performed strongly on ASL aptitude tests, including the program-required Virginia Quality Assurance Screening (VQAS), where most earn at least the professionally certifying Level III rating (80–94% proficiency). Since program inception in 2015, most (~90%) ASL student participants went on to careers as professional interpreters. In the past 4 years, three of the five ASL student interpreter respondents reported

having an ASL job that uses STEM signing- a direct result of the unique hands-on training they received in communicating science vocabulary and techniques. These students were specifically recruited from ASL interpreting programs nationwide.

2.6 Program assessment

2.6.1 Scope

Prior work has well established the positive impact of summer research internships on science students (National Academies of Sciences, Engineering, and Medicine, 2017), including those with disabilities (e.g., Cavender et al., 2009), however, less is known about the conferred benefits to and the experiences of participants in intentionally designed programs that integrate “disabled” and non-disabled students in research activities (Gin et al., 2022). Further, while Gormally and Braun (e.g., Majocha et al., 2018; Braun et al., 2018) have reported how UREs can improve the cultural competency of hearing mentors, few studies have explored how hearing students in programs providing opportunities to engage with DHH peers may contribute to their *Deaf awareness*⁴ as future practitioners. Here, for assessing program efficacy, we explore the outcomes conferred to all participants and how participation impacts hearing students’ awareness of Deaf culture and inclusive communication strategies.

2.6.2 Student researcher surveys

Mixed survey data on participants’ backgrounds, cognitive and noncognitive gains, and experiences have been collected since program funding in 2018 for assessment purposes. The survey consists of closed/Likert-type questions adapted from validated measures for assessing student researchers’ knowledge and skills (e.g., Maltese et al., 2017; Weston and Laursen, 2015) and psychological outcomes (e.g., sense of belonging, self-efficacy; Hanauer et al., 2016) as well as items commonly used to collect demographic (see NCES) and academic/career interest data (e.g., Harsh et al., 2011). To better understand program impact, closed and open response items were developed to ask about the nature of the participants’ experience, activities engaged in over the 10-week program, programmatic aspects involving DHH participants, and potential future refinements to help maximize the learning and social experience. Due to programmatic changes, pandemic-related variation in the SU21 program implementation, and shift in study focus, exit survey data were analyzed here from student researchers in the 2022, 2023, and 2024 summer programs.

Surveys were administered online near the end of the program to capture participants’ retrospective accounts comparable to other common summer URE assessments (Weston and Laursen, 2015). Closed/Likert-type survey data were descriptively analyzed in SPSS (version 24). Open-ended responses were analyzed using directed content analysis (Creswell and Poth, 2016). As the authors leading the assessment (JH, FT, IC, EM, AR, AS, TD, and SS) have not participated in the program or members of the DHH community, an iterative emergent approach was employed in identifying themes and codes from the data informed by preexisting work on DHH student research

⁴ As defined by Majocha et al. (2018), Deaf awareness refers to the learning about Deaf culture, identity, communication strategies, and ASL.

(e.g., Majocha et al., 2018) and conversations with program administrators. Each participant response was coded by two researchers independently after training intended to promote interrater reliability (Creswell and Poth, 2016), with follow-up discussions for consensus-making as needed. Descriptive statistics were used to examine trends within the coded data.

3 Results

3.1 Study population/sample

All student researchers in the program ($n = 147$) were invited to voluntarily complete the exit survey during the summers of 2022, 2023, and 2024. Data were collected from 72 participants (49% response rate) with 50% female identifying, 70% white, 30% first-generation, and 90% third-/fourth-year students. Most respondents (90%) were majoring in chemistry, biochemistry, and biophysical chemistry with the rest in other STEM fields (e.g., biology). Fifty-four percent of respondents had plans to attend graduate school in a STEM field after graduation, 21% working in a STEM field, 18% professional school, and 7% unsure of next steps. JMU students comprised 80% of the sample with the balance coming largely from other PUIs. Three of the 11 total DHH participants across summers (27%) completed the survey. Due to low DHH student response rates limiting generalizability and intent of the study questions, this article focuses on all summer program researchers across DHH and hearing groups.

3.2 Research-related outcomes

Students reported ranging outcomes relating to program participation. Ninety percent of survey respondents indicated they felt comfortable completing their summer research methods independently or could instruct others on how to complete them. Most students (>60%) reported confidence gains in the research-related areas of working independently to complete basic and advanced tasks, discussing results with mentors, interpreting and troubleshooting results, suggesting next steps, and collaborating scientifically. Thirty-five percent of students reported the building of research confidence as their greatest benefit, followed by the exposure to genuine research (26%), resume building/networking (13%), communication skill development (8%), and the application of classroom principles (6%) as well as others at <5% response rate (e.g., interest maintenance, basic skills).

Fifty-one percent of respondents indicated that the program helped guide their future academic or career intentions to some degree. When asked to elaborate, 55% of these students attributed the shift to a refinement of interests (e.g., identification of a specific study area), a 43% increase in area/research interests, and a 2% decrease of research interests. The following representational comments lend insight: “I have grown a more in depth understanding of how and why research is conducted, which interests me in potentially pursuing a career in the field” (Student 1, SU2023) and “I knew I wanted to go to graduate school, but I was not sure of the area that I wanted to study. This research experience helped me better understand that I was interested in pursuing materials chemistry” (Student 2, SU2024). Student responses highlighted a variety of interacting ways the

experience will help them achieve future goals, including skill and knowledge development (51%), improved readiness for graduate school (17%), and career readiness (32%).

Survey respondents agreed that the program positively benefited their sense of belonging in the field ($\bar{x} = 4.51$, $SD = 0.486$; 5-point Likert-scale); a key psychological predictor of science student persistence and success. Open comments further reinforced this outcome: “The experience made me feel like I do belong in this field and made me realize that I want to do research.” (Student 3, SU2023). Here, relating to the sense of belonging survey construct factors (Hanauer et al., 2016), >90% of all respondents reported that the summer program led them to come to think of themselves as a scientist/chemist, feel like they belong in the field, have a strong sense of belonging to the scientific community, and derive personal satisfaction from working on a research team. More than 80% of respondents indicated the experience made the daily work of a scientist appealing. In open response, most students (96%) reported how the various program events (e.g., social activities) positively impacted their experience (the balance was neutral), with 46% specifically describing benefits from new relationships. As expected, it is difficult to draw meaningful comparisons between hearing and DHH student groups due to the small sample size of DHH respondents ($n = 3$); however, no differences were qualitatively observed in outcome reporting.

3.3 Development of hearing students’ deaf awareness

Twenty-seven percent of responding hearing students ($n = 63$) reported having meaningful interactions with DHH peers on average two to five times per week, ~5% five to 10 times per week, and 18% > 10 times per week. Approximately 50% of hearing students indicated few/rare (0–1 times/week on average) interactions with other DHH researchers beyond hallway greetings, etc. Common settings for meaningful interactions between DHH and hearing students included social activities (identified by 80%), science communication events (71%), sign lunches (64%), lab activities (61%), research meetings (58%), and program housing (20%).

Hearing students were prompted to their biggest takeaway from interacting with DHH peers and faculty. Reported gains were coded into five categories for those that responded ($n = 47$). First, 37% of hearing student responses highlighted an *increased awareness of Deaf culture*: “I learned a lot about Deaf culture, and I learned better ways to communicate with [DHH] individuals, and the importance of their culture and experience especially in the world of science” (Student 4, SU2022) and “I learned a lot about the Deaf community and felt that I have learned how to be a more accepting and respectful person in relation to the Deaf community” (Student 5, SU2023). Second, hearing student responses (20%) highlighted gains in *development of ASL and non-verbal communication skills* “I think learning about sign language and finding a new way to communicate with people I could not before was really eye-opening” (Student 6, SU2022). Third, hearing student responses regularly featured (17%) an *increased awareness of accessibility and diversity needs in STEM*. As an example, a student commented “It makes me think about whether an activity or event is accessible to those who are deaf or

hard of hearing. Like when we went to the planetarium and it was dark—anyone who needed the sign interpreters would be [out of luck]. So, I would say my awareness has been increased” (Student 7, SU2023). Fourth, several hearing student responses (10%) described an *increased self-awareness in working with others of different backgrounds*: “Be patient and accepting of people from all backgrounds. You do not understand what another person may struggle with” (Student 8, SU2024) and “Be considerate of privilege and take that into account when telling someone about my science.” As it relates to specific program features, most hearing students described how the scientific communication events increased their awareness of audience needs in relation to STEM background knowledge (38%) or accessibility issues (19%).

Finally, a subset of hearing students reported *limited or no gains* from their interactions (17%). Of those that elaborated on this response, several cited having prior experience with/interest in the Deaf community or an inclusive mindset that informed their preexisting views. As an example, one hearing student noted. “I came in with a bit of prior knowledge of what Deaf culture is. I just was open to how it looks across different people (Student 9, SU2023).” Another commented “No [gains], I think it is very important to make chemistry open to anyone who wants to learn” (Student 10, SU2023).

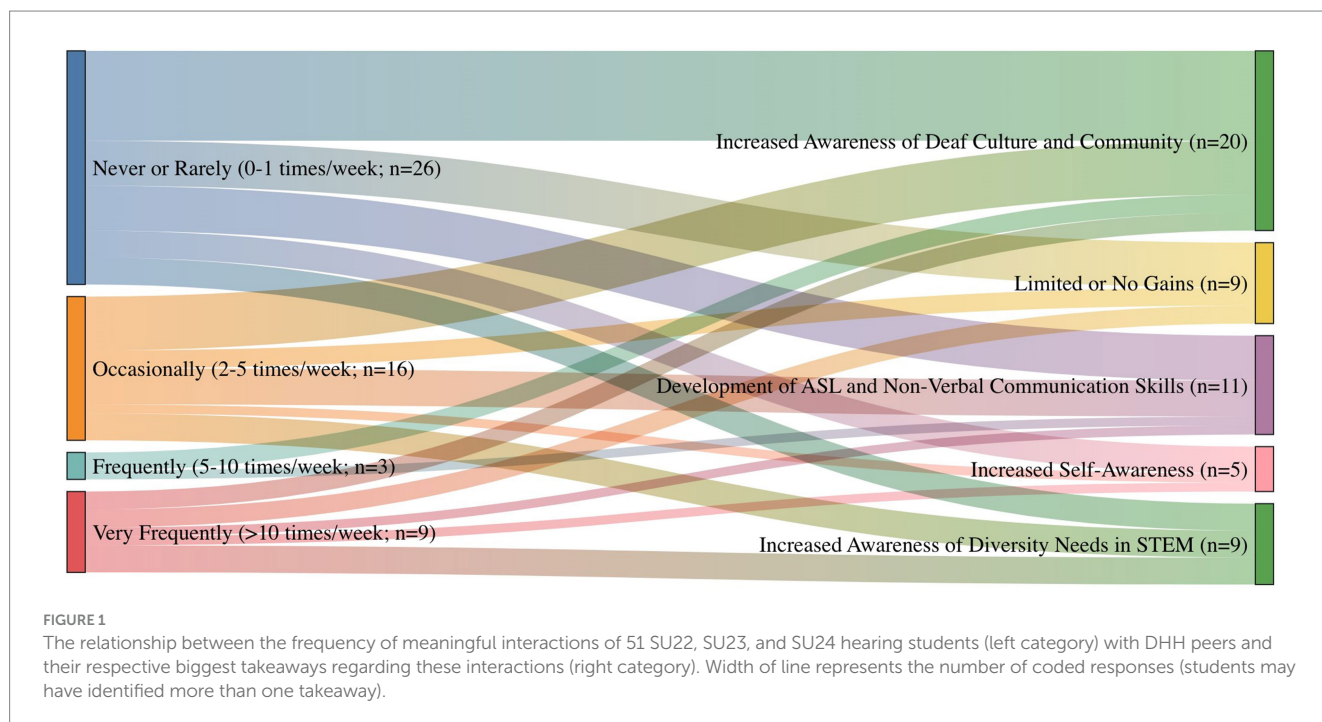
As seen in [Figure 1](#), the frequency of meaningful interactions with DHH counterparts did not substantially influence the “biggest takeaways” described above for hearing students. For example, 80% of students that never/rarely interacted with DHH peers reported some type of inclusion-related outcome (e.g., increased recognition of Deaf culture). These participants’ open responses suggest this reflects their program activities, increased awareness of the DHH research community, and/or personal interest. The following quotes espouse this view: “I did not interact much with peers or faculty who identify as deaf or hard-of-hearing, but I enjoyed sign lunch and learning sign language a lot. It was interesting to learn about

Deaf culture as well” (Student 11, SU2023) and “While I did not form personal relationships, I did learn so much about Deaf culture and how to communicate in a basic sense with a Deaf/hard-of-hearing person” (Student 12, SU2024). Similarly, no pattern was observed collectively for all other hearing students that occasionally, frequently, or very frequently interacted with DHH peers on a weekly basis, with several reporting having not made any specific gains—which may in part be attributed to their prior experiences with/interest in the DHH community.

4 Discussion

Access to undergraduate research as a high impact practice for *all* students is critical for the preparation of future practitioners and the advancement of science, more broadly. To this end, it is necessary to explore how UREs can be designed to increase the participation of students from traditionally underrepresented groups by offsetting systematic barriers. This article provides one of the few detailed accounts to the nature and impact of a summer program integrating DHH and hearing students in scientific research that models “best practice” recommendations for creating inclusive and accessible laboratory environments for DHH researchers. Strategies drawn from the literature (e.g., [Braun et al., 2017](#); [Listman et al., 2024](#)) respecting the needs and growth of DHH and hearing students were employed to offset common and environmental barriers, help cultivate the cultural competency of peers and mentors, and build community.

Early findings of this ongoing assessment point to the positive outcomes conferred to all program participants, though caution must be taken in generalizing results relating specifically to DHH researchers due to small sample size. Consistent with prior work on summer UREs for science students of varying backgrounds ([Laursen et al., 2010](#)), students across groups identified gains in research-related



competencies as well as the positive influence of the experience on their career preparation and intentions. Moreover, hearing and DHH students reported the program contributed to psychological outcomes (e.g., sense of belonging, self-efficacy) associated with STEM retention and persistence (Chemers et al., 2011).

Insight from hearing students highlighted how the program helped develop their cultural competence through an increased awareness of Deaf culture and communication skills necessary for navigating cross-cultural interactions. Interestingly, even sporadic interaction with DHH students through varying activities in research and social spaces increased the appreciation and understanding of Deaf culture for hearing students. As existing work in this area has focused largely on the successful engagement of DHH scholars in the research space, including mentor awareness and advocacy (e.g., Majocha et al., 2018; Listman et al., 2024), these findings help lend insight to how such intentional experiences can potentially guide the cultural competence of mainstream peers—and potential future practitioners—able to effectively communicate and work with people from diverse backgrounds.

On a practical level, this study highlights the effectiveness of intentional activities, as outlined in Section 2.3, relating to community building, science communication, mentor training, community building, and developing cultural awareness that are broadly transferable to other programs to decrease institutional and systemic barriers. The results point toward the value of intermixing DHH and hearing students and faculty in the laboratory (i.e., multiple groups, Deaf research mentors) to increase the potential for interpersonal interactions between group members in benefit to gaining experience working with others across cultures, cultural competence, communication skills, and affect (e.g., sense of belonging). Robust mentor training before the program begins, including topics like diverse communication approaches, promotes the creation of accessible and inclusive lab environments. Regular weekly activities for DHH and hearing participants in a Deaf-centered environment (e.g., sign lunch) to purposefully explore topics such as Deaf culture and Deaf/hearing communication improves cross-cultural understanding. The scheduling of frequent social events for all students builds community and promotes cultural awareness. Assembling a large and diverse community of DHH students, researchers, and on-/off-campus advocates leads to a robust network that helps navigate unforeseen administrative and practical barriers (e.g., how to teach and interpret research procedures in a fume hood) to optimize the experience.

This study has several limitations and recommendations for future exploration. Due to the nature of the REU program and number of DHH that can be adequately supported in the laboratory and social settings, most of the study sample consisted of hearing individuals. While this allowed insight into how such diversity-focused programs impact hearing students, future studies with a larger number of DHH and hearing participants could further explore group-specific program outcomes and how those outcomes come about. Such work could provide greater understanding of how the design features are perceived and their effectiveness in offsetting surrounding barriers for participants. Additionally, the survey data reported here are drawn from the self-reports of participants upon exiting the program. There is a need for future studies with former DHH and hearing participants to explore the longer-term effects and perceptions of such

programs. Retrospective accounts could inform decisions about transforming laboratory environments and lend insight into how cultural competence gained through UREs impact practitioners' later interactions and activities in STEM fields. Further work could also systematically study the experiences of and outcomes for student interpreters in these types of intensive programs given the need for ASL trained interpreters in higher education and STEM broadly (Palmer et al., 2025; Ott et al., 2020).

Visible and invisible barriers in STEM laboratory settings for students from traditionally underrepresented groups are often attributed to a lack of awareness by mainstream faculty and students (e.g., Gin et al., 2022; Laursen et al., 2010). The findings here highlight the benefits that result for all participants in programs intentionally designed to engage mainstream and underrepresented scholars in inclusive research environments. This includes the potential for mainstream students, as future practitioners, to develop cultural competence and empathy for others of differing backgrounds.

Data availability statement

The datasets presented in this article are not readily available because the datasets presented in this article are not readily available as they contain personal participant data. Requests to access the datasets should be directed to harshja@jmu.edu.

Ethics statement

The studies involving humans were approved by Indiana University and James Madison University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JH: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. CH: Funding acquisition, Project administration, Writing – review & editing. IS: Funding acquisition, Project administration, Writing – original draft, Writing – review & editing. NW: Writing – original draft, Writing – review & editing. IC: Data curation, Formal analysis, Visualization, Writing – original draft. FT: Data curation, Formal analysis, Writing – original draft. AR: Formal analysis, Writing – original draft. EM: Formal analysis, Writing – original draft. AS: Formal analysis, Writing – original draft. SS: Formal analysis, Writing – original draft. TD: Formal analysis, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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