Learning From a Pandemic: Redesigning with Universal Design for Learning to Enhance Scientific Skills (Practice Brief)

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Abstract

Colleges are becoming increasingly diverse, including strengthening representation of students with disabilities in STEM (Science, Teaching, Engineering, and Math) fields; however, representation still lags behind national trends. To adapt to this changing demographic and improve representation, STEM college professors must be prepared to grant equitable access to the STEM curriculum and enhance scientific communication skills. This practice brief outlines how a college science faculty applied the Universal Design for Learning (UDL) framework to improve scientific communication skills equitably among college students with diverse needs during a 10-week NSF-REU (National Science Foundation – Research Experiences for Undergraduates) at the host institution summer program during the COVID-19 pandemic. It also provides recommendations for supporting students with disabilities (i.e., chronic illness, chronic pain, depression, anxiety, and attention deficit hyperactivity disorder [ADHD]), which may have been exacerbated by the COVID-19 pandemic. Applying the UDL framework increased student confidence in applying the scientific method and led to gains in students' perception of their ability to use their skills to solve scientific problems. STEM faculty can use the lessons outlined in this work to develop inclusive and accessible STEM programs. Moreover, this work highlights the need for STEM faculty to involve Disability Services coordinators as active members in research programs to ensure equity and inclusion.

Keywords: universal design for learning, scientific skills, higher education

College students with disabilities are an underrepresented population in both higher education and the STEM (Science, Teaching, Engineering, and Math) community. The Center for Disease Control [CDC] (2022) reports that 26% of the general population has a disability, as compared to only 19.5% of enrolled four-year college students (National Institute on Disability, Independent Living, and Rehabilitation Research [NIDILRR], 2023). Federal data show that students with and without disabilities enroll in STEM programs at identical 28% rates (National Center for Science and Engineering Statistics [NCES], 2021), but only 16% of the disabled population has a bachelor's degree, compared to 39% of the total population (NIDILRR, 2023). This gap is partially explained by a lack of support (Reardon & Unruh, 2021), and many disabled students not completing their degrees (Staats & Lee, 2020). From these data, we can conclude that insufficient supports are available for current university students with disabilities in STEM fields.

Diversity is a focal point in higher education (Clayton, 2021), requiring institutions to evaluate how courses are meeting the needs of the student population (Reardon & Unruh, 2021). Postsecondary institutions are guided by legislation to support these efforts. Section 504 of the Rehabilitation Act (1973) requires institutions that receive public funds to provide reasonable accommodations to individuals with disabilities. This anti-discrimination legislation has prevented exclusion based on disability and has

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increased opportunities for individuals with disabilities to attend higher education. These efforts have not been enough, though, which has prompted discussion around the use of universal design to ensure equitable access and support. The Higher Education Opportunity Act (HEOA, 2008) was the first piece of education-focused legislation to embed Universal Design for Learning (UDL), and provided guidance to create a more meaningful, dynamic, inclusive environment for all learners (e.g., students with disabilities and students at risk due to trauma; Reardon & Unruh, 2021).

A major complicating factor for students with disabilities was the COVID-19 pandemic, which was extremely disruptive to higher education and society at large. The pandemic necessitated remote work policies to comply with social distancing and meet federal guidelines. This state of high societal stress led to new disabling experiences and exacerbated some existing ones. In response to the COVID-19 pandemic, many new teaching modalities, including hybrid approaches and student directed synchronous/asynchronous learning, were widely used for the first time by some faculty. Many of these teaching modalities fall within UDL best practices and have the added benefit of creating a more equitable space for all students, but especially students with disabilities.

The purpose of this paper is three-fold: (a) provide an overview of how the NSF-REU (National Science Foundation – Research Experiences for Undergraduates) program at the host institution adapted to support student learning during the first year of COVID-19; (b) demonstrate how the UDL framework can be applied to enhance scientific communication skills during summer science programs to support the academic success of a diverse undergraduate student population; and (c) deliver recommendations to identify how students with disclosed, undisclosed, and recently acquired disabilities can be supported in STEM programs using UDL evidence-based practices.

Depiction of the Problem

There is a pressing need to support all students who are interested in STEM fields and teach them the skills they need to succeed in scientific careers. Within the scientific community, the adoption of UDL principles is an ongoing discussion in response to the systemic exclusion of overlooked populations, such as people with disabilities (Nasri et al., 2021; Staats & Lee, 2020). COVID-19 required the scientific community to make some changes that are consistent with UDL, yet many may not understand the continued benefits of utilizing UDL.

Universal Design for Learning

UDL, built from universal design, is a framework that enhances students' learning through accessible classroom content (CAST, 2018; Meyer et al., 2014). UDL allows progress toward removing obstacles and promoting classroom equity by offering content through multiple means of engagement, representation, action, and expression (CAST, 2018). The goal of the multiple pathways is to maximize opportunities for students to learn and demonstrate mastery of materials while minimizing potential barriers. UDL places the responsibility on faculty to be accountable for their accessible design so that students are able to access content in an engaging manner (Meyer et al., 2014). Nasri et al. (2021) compared learning through UDL and traditional instruction of rural students' attitudes toward STEM. They found that students who participated in the UDL group had improved positive attitudes towards STEM fields. Using UDL to ensure STEM programs and courses include all learners can reduce barriers and promote access and engagement, specifically students with disabilities (Staats & Lee, 2020).

UDL promotes independence and social inclusion necessary in STEM (Staats & Lee, 2020) and online learning (Yang, 2023). In the REU program's redesign, UDL provided flexibility in how information is represented, giving learners the ability to build foundational knowledge through direct engagement, introduce and support interests, and promote both action and expression so that students had multiple avenues to demonstrate their mastery (e.g., presentation, paper, individual discussions). The findings presented in the Evaluation of Outcomes support Nasri et al.'s (2021) work by showing how students' self-confidence and attitudes towards STEM topics improved through our UDL inspired adaptations.

Description of Participants and the Program

The Department of Chemistry and Biochemistry at the host university runs a 10-week NSF-REU program that has trained over 190 undergraduate researchers over the last 19 years. During this time, there has been 50% women involvement in the program, 46% men, and 4% non-binary. Over 92% of students are from the Appalachian region, an economically disadvantaged area, and attend institutions that lack resources for summer research programs. The majority of participants have been white (83%), with the remaining 17% coming from underrepresented groups. During the course of the summer program, 25% of the students self-disclosed disability as chronic illness, chronic pain, depression, anxiety, and attention deficit hyperactivity disorder [ADHD]. Participants of the NSF-REU program are matched with two mentors, one from the host University and another from the student's home institution. Typically, students live on campus while working on their research projects; however, campus living was not an option during COVID-19. The host University received IRB approval to collect data from individuals attending the summer program.

As previously stated, the COVID-19 pandemic was highly disruptive and required significant programmatic restructuring to adapt to an online-only paradigm. Beyond the technical and logistical aspects, the pandemic exacerbated the mental health needs of students, who required additional support (Barbieri et al., 2021). However, the move to online instruction created an unanticipated opportunity to redesign the program to be intentionally grounded in UDL. The virtual environment allowed students to participate from individual spaces, while video recording permitted both repeat watching and asynchronous learning, all aspects that supported UDL. Overall, the faculty noted that both those who did and did not self-report disability were able to succeed in a STEM research program during the pandemic.

Working closely with their mentors, the participants chose a scientific problem and designed a hypothesis to examine their proposed project. The program cumulates with all students presenting the products of their research at regional and/or national conferences. More specifically, to enhance student development, students attended classes, labs, and workshops ranging from 45-90 minutes to discuss current issues in STEM (e.g., ethics, electronic lab tools, how to search databases effectively). These educational opportunities allow students to explore needs in their field of interest and future career goals along with developing communication skills through scaffolded exercises (Montgomery et al., 2022). To date, over 95% of the students who participated in the summer 10-week program subsequently enrolled in a graduate program (i.e., Ph.D., medical, or dental school).

Each guideline of UDL was addressed during the program. Use of intentional scaffolding along with a mixture of presentation, recordings, one-to-one meetings, and student directed learning supported students to engage with the material through their own optimal representation. Finally, by building in biweekly oral presentations and written assignments, along with individual discussions with mentors, and a final conference presentation, the students received many different ways to express what they had learned and demonstrate mastery.

Evaluation of Observed Outcomes

Surveys and performance outcomes were used to evaluate the effectiveness of the program. Data on student self-perception was collected at the start and end of the program for the purposes of institutional reporting and tracking student progress. The researchers used an informal Likert survey to understand students' self-perception of their gain in scientific skills across the program. Statistically significant changes from pre- to post-course indicate that individuals who attended the program reported meaningful impact towards their progress in STEM fields (See Table 1).

We observed strong positive gains in students' confidence in drawing data-based conclusions using the scientific method from the start to the end of the program (Montgomery et al., 2022). Qualitative data informed participants' confidence with this program. Participants reported that revisiting recorded lectures minimized feeling overwhelmed by new material. They also discussed appreciation of the program embedding mental health days for students to take care of non-academic needs. Finally, individuals in the program stated the benefit of asynchronous STEM topics tied to real world problems allowing them to see how issues were solved. We saw improvements in students' perceptions of their ability to conceptualize and present scientific data in both written and oral formats. Beyond the survey data, a clear qualitative indication of this growth was how the students' weekly presentations changed as assessed by the faculty, with each student gaining confidence and competence. This was aided through aspects of UDL, such as recorded background lectures that allowed students to rewatch prior material as needed to build mastery. Moreover, having students participate in group discussions and presentations through Zoom permitted students with anxiety to engage in early weeks with video off. By the end of the summer all students reported being comfortable presenting live with full video. This cumulated with the students presenting at a local conference, and several also presenting at national conferences (e.g., American Chemical Society Spring Conference).

Implications and Transferability

While COVID-19 generally hindered education, this online summer program offered many benefits to participants that helped them adapt and academically thrive. Indeed, during the program students experienced many difficulties. For example, students lacked access to the internet, acquired disabilities from COVID-19 (e.g., long-haul COVID, anxiety),

Table 1

Changes in Student Study Skills Across the Program

Presently I can…	Average Pre	Average Post	Significance
Draw meaningful conclusions from generated scientific data	M =3.00	M =3.86	p<0.05
Prepare and give scientific reports or papers	M =2.94	M =4.04	p<0.05
Prepare and give oral presentations	M =3.44	M = 4.27	p<0.05
Find research articles related to my research	M = 4.06	M = 4.50	p<0.05
Critically read research articles to understand the main results	M = 3.22	M = 4.14	p<0.05
Draw meaningful conclusions from generated scientific data	M = 2.94	M = 3.86	p<0.05

Note. Data is reported as average (mean) N=10. Significance was determined using a T-test, comparing the starting populations. Answers quantized with 1: not at all, 2: just a little, 3: somewhat, 4: a lot, 5: a great deal.

or experienced new responsibilities (e.g., caring for a younger sibling). Knowing the struggles students experienced due to the pandemic, the faculty redesigned the summer program using the UDL framework to offer multiple learning opportunities to demonstrate mastery.

The REU program provided pathways for students to request support from their close mentors and faculty, along with accessing meaningful accommodations that can be applied to all programs across the university. For example, faculty scaffolded and recorded all lectures so that students could review past lessons and prepare for classes and presentations, and assigned designated mental-health days so that students would be able to request meetings, catch up on content missed or not mastered, attend hospital appointments, or take a break. Finally, faculty required one-to-one and group meetings with students focused on STEM careers of interest to align practicing and applying the scientific problems each week. These meetings allowed students to see the scientific method applied in future job opportunities. Minor changes made to support students for the online program and classroom development (e.g., recorded lectures, group problem-solving meetings) can have significant impact for students with disabilities majoring in STEM as all participants with disabilities who attended the online redesign either pursued a career or graduate degree in a STEM field. With these simple changes, STEM faculty can easily adopt and implement UDL to create more inclusive learning opportunities.

Limitations

While the dissemination of the program has strengths, limitations were identified. Some participants did not have internet access, which impacted online learning. To address this initial limitation, wireless hotspots and necessary technology (i.e., computers and required software) were provided for participants as needed. Unreliable access to internet reinforced the importance of allowing participants to access materials through both asynchronous and synchronous pathways. A second limitation was that not all students disclosed their disabilities with disability support services at the University; they only confided with faculty mentors. Faculty may not have had background knowledge to support students' accommodations adequately beyond what was requested or implemented through UDL. Future program replication must consider participants' access to the internet and build in essential support systems to ensure accessible formats of communication to effectively support students' needs. For example, the pandemic caused some disabilities to surface in ways participants were not expecting. Some faculty advisors needed more knowledge to support students proactively and not reactively.

A third limitation is the sample size. We researched the group of students as a whole without collecting data separately to conduct a comparison of students with and without disabilities. Therefore, while we can say that the student body as a whole reported statistical improvement, we cannot say with certainty that those students with disabilities improved to a similar degree. Furthermore, this population includes highly driven students who applied to work in a science summer program, which shows a high level of motivation and dedication, and indicates that this approach has good transferability for similar summer programs. Finally, the quantitative data we collected used a self-reporting Likert scale. However, even with these limitations the results obtained suggest that this program was effective at incorporating UDL strategies to improve supports and learning for students with and without disabilities.

Future Recommendations

This summer program yielded three recommendations for future implementation for STEM faculty to redesign coursework and programs with a focus on UDL. First, due to COVID-19, many undergraduates experienced emerging mental health needs (Chirikov et al., 2020). The researchers recommend building in at least one mental health day as a method for improving student resiliency and removing barriers that may be caused by anxiety, stress, or exhaustion. Moreover, by providing recorded lectures and real-world problems, students will be able to review materials and identify issues, while ensuring they are taking care of their needs associated with their disability. Furthermore, these breaks will allow all participants, including faculty, to adapt to emergent issues.

A second recommendation requires collaboration between STEM and education faculty with disability support services (DSS). Students who participated in this program benefited from the increased flexibility allowed by remote work. This could be enhanced by DSS providing faculty with a foundational understanding of disabilities, how to encourage disclosure, and how to implement remote work, recorded lectures, and flexible schedules to accommodate students with disabilities. Working with DSS will satisfy new and upcoming requirements from funding agencies (e.g., NSF grants) for improved faculty professional development. Collaboration with the faculty in a school of education program can support the implementation of differentiated instruction and UDL throughout the program. Learning multiple ways to deliver science-focused content can lessen barriers experienced by students with disabilities and promote an inclusive and accessible field. Further, a partnership with the school of education could provide continuous learning opportunities to implement evidence-based teaching strategies grounded in the UDL framework (e.g., face-to-face lectures, labs, remote learning, and real-world problems) to minimize challenges related to instruction while maintaining high expectations for all students.

A final recommendation would be to allow DSS coordinators to be active members during the initial discussions, design, and implementation of campus programs that could remove barriers faced by students with disabilities while educating faculty on minimizing obstacles that may unknowingly arise from instruction. This support would require institutions to fund resources and staff to adequately train faculty on UDL techniques. For example, the summer program was reactive to students' needs and disability accommodations that emerged from COVID-19. Designing the summer program utilizing DSS's knowledge regarding UDL, accessibility, and student needs may have lessened the stressors of changing the summer program online.

Since many DSS offices have budget constraints, educating faculty through online modules could support the accessible design and protect the time of DSS personnel. DSS staff have unique insight and expertise in accommodating students with disabilities and those in marginalized populations and promoting an inclusive learning environment for all students. DSS could support faculty professional development by collaborating with schools to disseminate knowledge of best practices in higher education. These online modules can support faculty with simple ideas to ensure course information is accessible to all learners (e.g., PowerPoints support screen readers and closed captioning used in recorded lectures).

Conclusion

Universities have a unique opportunity to create dynamic, accessible material to promote the inclusion of excluded populations, namely students with disabilities (Staats & Lee, 2020). The COVID-19 pandemic necessitated university professors to adapt, grow, and explore new modalities for teaching students. In this report, we discussed how the UDL inspired adaptations made to a summer research experience led to an improved support network for students with and without disabilities. This included multiple opportunities to practice and demonstrate mastery of the scientific method, the ability to engage with material in real time or asynchronously, and greater flexibility in how students engaged with the material. These lessons are transferable to different STEM programs and other departments for increased inclusion during the academic year and in research programs. As we move through and beyond the pandemic, it is important to continue to implement creative solutions to ensure removal of barriers to provide consistent pathways of inclusion of marginalized groups in the STEM fields.

References

Barbieri, P. N., Giuntella, O., Saccardo, S., & Sadoff, S. (2021). Lifestyle and mental health 1 year into COVID-19. *Science Reports, 11*,1–6. https://doi.org/10.1038/s41598-021-02702-4

CAST (2018). *Universal design for learning guidelines version 2.2*. Retrieved from http://udlguidelines.cast.org

Centers for Disease Control and Prevention. (2022, July 6). *Disability impacts all of us*. https://www.cdc.gov/ncbddd/disabilityandhealth/infographic-disability-impacts-all.html#:~:text=26%20percent%20(one%20in%204,is%20highest%20in%20the%20South

Chirikov, I., Soria, K. M., Horgos, B., & Jones-White, D. (2020). *Undergraduate and graduate students' mental health during the COVID-19 pandemic.* SERU Consortium, University of California Berkeley and University of Minnesota. https://cshe.berkeley.edu/seru-covid-survey-reports

Clayton, T. B. (2021, January 13) Refocusing on diversity, equity, and inclusion during the pandemic and beyond: Lessons from a community of practice. *American Council for Education.* https://www.higheredtoday.org/2021/01/13/refocusing-diversity-equity-inclusion-pandemic-beyond-lessons-community-practice/

Higher Education Opportunity Act of 2008, 110 U.S.C. Pub. L. No. 110-315, 122 Stat. 3078 (2008). www.govinfo.gov/content/pkg/PLAW-110publ315/pdf/PLAW-110publ315.pdf

Meyer, A., Rose, D., H., & Gordon, D. (2014). *Universal Design for Learning: Theory and practice.* CAST Professional Publishing.

Montgomery, T. D., Buchbinder, J. R., Gawalt, E. S., Iuliucci, R. J., Koch, A. S., Kotsikorou, E., Lackey, P. E., Lim, M. S., Rohde, J. J., Rupprecht, A. J., Srnec, M. N., Vernier, B., Evanseck, J. D. (2022). The scientific method as a scaffold to enhance communication skills in chemistry. *Journal of Chemical Education, 99*, 2338-2350. https://doi.org/10.1021/acs.jchemed.2c00113

Nasri, N., Rahimi, N. M., Nasri, N. M., & Talib, M. A. A. (2021). A comparison study between universal design for learning-multiple intelligence (UDL-MI) oriented STEM program and traditional STEM program for inclusive education. *Sustainability, 13*(2), 554–566. https://doi.org/10.3390/su13020554

National Center for Science and Engineering Statistics. (2021). *Women, minorities, and persons with disabilities in science and engineering: 2021* (Special Report NSF 21–321). National Science Foundation. https://ncses.nsf.gov/wmpd.

National Institute on Disability, Independent Living, and Rehabilitation Research (2023). *Annual report on people with disabilities in America: 2023.* https://disabilitycompendium.org/sites/default/files/user-uploads/Accessible-Annual%20Report%20---%202023%20---%20Accessible.pdf

Reardon, K., & Unruh, D. (2021). Universally Designed Learning in postsecondary education: A synthesized framework. *The Journal of Faculty Development, 35*(2), 27–34. https://www.proquest.com/scholarly-journals/universally-designed-learning-postsecondary/docview/2522431605/se-2?accountid=10610of the Rehabilitatio

Staats, S. & Lee, A. (2020). Introduction to special issue on increasing participation in higher education STEM programs. *Education Sciences, 10*(5), 139. https://doi.org/10.3390/educsci10050139

Yang, M., Lowell, V., Long, Y., & Farmer, T. (2023) Designing for accessibility in online learning: A design case. *Journal of Postsecondary Education and Disability, 36*(1), 75–87.

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