Board 254: Emphasizing Broader Impacts and Societal Benefits in a Developing ERC

Gina Ristani, University of Minnesota, Twin Cities

I am a recent graduate of the Psychological Foundations of Education: Learning and Cognition Master's Program at UMN-TC and am excited to begin my new role as NSF ERC ATP-Bio's Diversity and Culture of Inclusion Education Program Specialist. My passion lies in building my skills in program evaluation to help measure and support cultural responsivity and equity in educational organizations.

Keisha Varma, University of Minnesota, Twin Cities
Seth Thompson, University of Minnesota, Twin Cities

Dr. Thompson is the current Engineering Workforce Development Program Manager for ATP-Bio and has previously held faculty appointments in the Department of Biology Teaching and Learning at the University of Minnesota and on the Faculty of Engineering and Science at the University of Agder in Kristiansand, Norway. His published work includes papers on innovative approaches to undergraduate research, equitable science education, and professional development for early career scientist.

©American Society for Engineering Education, 2024

Emphasizing Broader Impacts and Societal Benefits in a Developing ERC

Gina Ristani, Seth Thompson, Keisha Varma

Department of Educational Psychology, University of Minnesota

Abstract

Research is crucial to humanity's technological and theoretical advancement. It is equally important research be conducted by a diverse, representative workforce. Sustained efforts by academic and industrial institutions to increase diversity in research identify many factors influencing recruitment and engagement of underrepresented minority (URM) students in Science, Technology, Engineering, and Math (STEM) research. One promising approach to increase diversity of undergraduates in STEM disciplines focuses on communicating culturally valued outcomes of the research being conducted (Estrada et al., 2016). We aim to develop a better understanding of how to support communication of the broader impacts and societal benefits of research conducted within an National Science Foundation (NSF) funded engineering research project. The main impact of this work is intended to be an increase in representational diversity in STEM through imparting the meaningfulness of research to URM students.

Keywords: broader impacts, diversity, STEM, societal benefits

Motivation

We live in a world surrounding us with the latest research findings and current technological or theoretical breakthroughs advertised at every turn. But when was the last time you actually thought about why research is important to society, and why it is important to you? Research serves to advance human knowledge and capabilities beyond our wildest dreams. Broader impacts and societal benefits of research are innately understood by the individuals whose lives are impacted by that research, but not always by the researchers themselves. In this context, the role that the broader impacts and societal benefits of research may play in motivating pursuit of STEM careers, especially those from underrepresented backgrounds, may serve as even further benefit to humanity. The importance of diversity in the research workforce need not be understated - Freeman and Huang (2014) established that greater ethnic diversity in research teams supports higher-quality work and positive engagement with subsequent publications. Diversity's role in bolstering the STEM talent pool should not be understated as it serves to advance the ability of the United States to compete in the global marketplace.

In the present study, we aim to develop a richer understanding of the broader impacts and societal benefits of research conducted within an NSF engineering research project. The project community consists of research teams across six universities in the U.S. An aspect of the project is to improve the communication of the broader impacts and societal benefits provided by the community's research in engineering. The project focuses its mission not only on the engineering research necessary to advance the field, but on the need to educate an engineering workforce that is a demographic reflection of the current and future nation so we may maximize the impact of engineering technologies on society. This investigation was undertaken through two approaches. Primarily, we sought to understand to what extent researchers are communicating the broader impacts of their work. In addition, we explored the ways in which researchers communicate those impacts.

Theoretical Background

Efforts to increase the representational diversity of the research workforce have studied a plethora of factors impacting motivation and retention of underrepresented minority students in academic research. As defined by NSF, underrepresented minorities include those who have lower representation in STEM employment and education than their representation in the U.S. population; specifically Blacks or African Americans, Hispanics or Latinos, and American Indians or Alaska Natives (NSF, 2024). Communicating specific societal and broader impacts of research conducted by students may in fact play a key role in motivating and retaining underrepresented minority students to continue their participation in academic research (Estrada et al., 2016).

Scientists often refer to the meaningful nature of their work when asked why they conduct research. Current findings encourage adoption of academic and scientific values to increase the likelihood underrepresented minority (URM) students pursue a science career. But we know from findings in the learning sciences, task value is a stronger motivator of task motivation than expectancies for success (Xiang et al., 2003; Wigfield et al., 2009). Thus, one's motivation to continue work is sustained more so when work is personally or culturally valuable to the individual. For URM students, collectivistic values which emphasize communally beneficial actions may play a stronger role in their motivation and overall retention. Speaking to cultural experiences shaping students' prosocial actions is a crucial step in encouraging URM motivation and persistence in STEM fields (Allen et al., 2015).

Research also shows evidence URMs tend to engage in science for altruistic reasons in pursuit of valued social causes (Seymour and Hewitt, 1994; Miller et al., 2000). In the context of these findings, the ideal workforce of diverse STEM professionals seems likely to not only have an understanding of, but a deep and motivating meaning derived from, the benefit their work provides to the world and how they are personally contributing to it. But this can only be achieved when the deeper benefit of and meaning behind research is first clearly communicated and emphasized to researchers as they conduct their work.

According to the NSF, broader impacts are the “potential (for your research) to benefit society and contribute to the achievement of desired society outcomes,”. Some examples of societal outcomes include public engagement, education, inclusion, societal wellbeing, national security, strengthened infrastructure, and economic competitiveness, among others. The Ethical, Legal, & Societal Implications (ELSI), of an engineering research project refers to the analysis of the societal implications of novel and emerging research and associated or resulting technological advancements (Ogbogu & Ahmed, 2022). Engineering projects such as this enable society to have a better quality of life, and be more resilient, productive, and safe. Each NSF-funded engineering research project is expected to have a transformational positive impact on significant societal challenges and opportunities. The Broader Impacts criterion encompasses the potential to benefit society and contribute to the achievement of specific, desired societal outcomes.

For research to have a broader impact, it should empower people to accomplish a goal tomorrow they were unable to accomplish in the past. So, we ask researchers to consider "Who can your research empower?" In some cases, beneficiaries will include students, early career investigators, and other academics. In other cases, it is possible to go further and consider other people who, and organizations that can use proposed research to advance science or improve others' quality of life. This consideration can include communities, public-service organizations and entrepreneurs who can use the research to innovate. Researchers can consider specific communities, organizations, or populations whose quality of life can be improved by new research. Consistent with the term "broader," we encourage researchers to think expansively about how their work can benefit others. Even when a project's immediate societal benefits are not apparent, and probabilities of particular outcomes are difficult to calculate, researchers can help others understand the potential public value of their work by articulating broadly beneficial outcomes becoming possible as a result of their proposed course of action. Additionally, we ask researchers to consider concrete steps they can take to make these effects more likely. Here, researchers have an opportunity to offer forthright, feasible, and (where possible) verifiable plans for converting their work's intellectual merit into broadly beneficial outcomes.

Objectives

Our primary objective was to understand the extent to which researchers are communicating the broader impacts of their work. Through observation of research presentations conducted by community members, we quantified the number of references to societal and broader impacts, among other factors, that researchers shared when presenting their work. This design enabled us to observe changes over time, addressing the following research questions:

1. Are researchers communicating broader impacts and societal benefits of their research?
2. Does educating researchers on broader impacts and societal benefits of their research increase their communication of those impacts?

3. Is there a difference between senior and early career scholars in the way they communicate broader impacts and societal benefits of their research?

Our secondary objective was to illuminate the ways in which researchers communicate broader impacts. We conducted a follow-up qualitative analysis of how our research community actually describes the broader impacts and societal benefits of their work in their own words. We asked for our community to share their thoughts in response to the following research questions:

1. What are some examples of the broader impacts and societal benefits of your research?
2. Why does [the engineering research project] encourage you to include broader impacts and societal benefits in your research outputs?

The overarching intention of our qualitative analysis is to better understand how the societal benefits that the engineering research project emphasized in its NSF proposal compare to the benefits reported by the researchers themselves. We also hope to improve our understanding of what researchers perceive as reasons for including these benefits in the first place, following the efforts that the engineering research project team has made to encourage the importance of this communication in research outputs over time.

Methods

How Often Are Broader Impacts Communicated?

The primary objective of this study was conducted quantitatively via survey and observation of research presentations in an NSF-funded engineering research project. Our engineering research project focuses extensively on ethical and public policy considerations around engineering so any technology developed by the project can be effectively translated to public benefit. Our members, consisting of both faculty and trainees (undergraduates, graduate students, research staff/technicians, and postdoctoral researchers) are committed to promoting this focus in their work. We aimed to elevate this aspect of the engineering project's research and innovations by intentionally providing guidance and feedback on societal and broader impacts. Specifically, we discussed broader and societal impacts in the context of research that has potential to impact URM communities, as an approach to utilizing communication strategies that resonate with URM students.

First, we observed presentations at the spring 2021 project meeting. We then held a seminar on the topic of Sharing the Broader Impacts and Societal Benefits of Your Research for all involved researchers in late spring 2021. We were then able to observe presentations in the fall 2021 project meeting and spring 2022 project meeting and compared the number of references to societal and broader impacts in presentations before and after the seminar (at two time points). Our initial coding rubric included the coding categories: broader impacts, societal impacts, diversity, culture, inclusion, equity, and ethics. Any reference to any of the seven coding categories in an individual's presentation counted as a point in that category (see Table 1). Each presenter was given a total sum score out of seven for the number of categories they included in their presentation.

We also conducted a brief "pulse" survey of project members after the spring 2022 project meeting, to gauge how individuals self-reported whether they consider societal impacts and challenges facing diverse, underserved populations in their work, along with whether their research lab explicitly discusses research ethics. We were able to compare responses by project role, distinguishing between faculty members and trainee members (see Table 2).

How Are Broader Impacts Communicated?

The additional objective of this study was conducted qualitatively with responses from transcribed interviews and survey responses. 30 total responses were received out of 51 researchers with up to date contact information who were emailed out of the 89 total presenters included in our poster/presentation analysis. Researchers were asked to schedule a Zoom interview or complete a survey to respond to the two questions: "What are some examples of the broader impacts and societal benefits of your research?" and "Why does [the engineering research project] encourage you to include broader impacts and societal benefits in your research outputs?".

Taking an inductive content analysis approach (Thomas, 2006) to our qualitative data, we reviewed participants' responses in order to identify the common themes and categories participants generated regarding shared examples of broader impacts and societal benefits, and their understanding of why the engineering research project emphasizes the importance of communicating these impacts in research outputs. Consideration of a deductive content analysis (Azungah, 2018) based on the pre-identified broader impacts and societal benefits of the engineering research project provides the following three main categories of impact due to engineering research; healthcare, biodiversity, and food supply/sustainability. Though responses did largely align with these three themes, we were interested in exploring the additional, more organic, themes that arose from the inductive analysis of responses, both in regards to the impacts themselves, but also the reasons behind why we encourage communication about these impacts in research outputs.

Data Sources

Primary quantitative data sources included research presentations, including posters and slideshows, and survey responses, from members of a large NSF-funded engineering research project. Presentations were observed at three time points, the spring 2021 project meeting, fall 2021 project meeting, and spring 2022 project meeting. Presentations were conducted by faculty members as well as trainees (undergraduates, graduate students, research staff/technicians, and postdoctoral researchers). Surveys were administered by project leaders in fall of 2022. Primary qualitative data sources included recorded and transcribed interviews via Zoom or via written survey responses in fall of 2023. Data collection is ongoing and expected to be continued for the duration of the engineering research project, until 2030.

Results

How Often Are Broader Impacts Communicated?

The spring 2021 project meetings had the highest mean score out of all three time periods ($M = 2.05$, $sd = 1.05$, $N = 37$), while the fall 2021 project meeting ($M = 1.5$, $sd = 1.38$, $N = 47$) and spring 2022 project meeting ($M = 1.41$, $sd = 1.66$, $N = 29$) had comparable mean scores (see Figure 1). When assessing mean scores by role in spring 2021, faculty ($M = 2.44$, $sd = 1.67$, $N = 9$) mentioned broader impacts and societal benefits more on average than trainees ($M = 1.93$, $sd = 0.77$, $N = 28$). This was consistent in fall 2021, with faculty ($M = 2.82$, $sd = 1.83$, $N = 11$) again referring to broader impacts and societal benefits more on average than trainees ($M = 1.09$, $sd = 0.89$, $N = 36$) in their research presentations. Though no data on faculty presentations were collected for the spring 2022 project meeting, trainees had a similar mean score as they did in prior meetings ($M = 1.41$, $sd = 1.66$, $N = 29$) (see Figure 2). In all, faculty scores remained consistently higher than trainee scores, which varied more over time.

Before the seminar on Sharing the Broader Impacts and Societal Benefits of Your Research in late spring 2021 was held, the mean scores of those who attended ($M = 2.0$, $sd = 0$, N

= 5) and those who did not (M = 2.06, sd = 1.15, N = 31) were nearly the same. For those who did attend the seminar, though their fall 2021 project meeting mean score was relatively low (M = 0.8, sd = 0.83, N = 5), their spring 2022 project meeting score increased noticeably (M = 2.77, sd = 1.92, N = 9). This is contrary to those who did not attend the seminar, whose mean scores decreased over time, showing comparably lower scores in fall 2021 (M = 1.59, sd = 1.41, N = 42) and again lower in spring 2022 (M = 0.8, sd = 1.11, N = 20) (see Figure 3).

As seen in Table 2, faculty and trainees differed across their self-reports on three topics; whether they consider societal impacts, consider the challenges facing diverse, underserved populations in their work, and whether their research lab explicitly discusses research ethics. Faculty reported a widespread 90% agreement (N = 10) that they consider all three of these topics. Trainees, though similarly agreeing that they consider societal issues (94%), diverged from faculty. They reported only 64% agreement with considering challenges facing underserved populations, and 44% agreement that their labs discussed ethics (N = 16).

Thus, we can see that researchers are indeed communicating broader impacts and societal benefits of their research, but we need further investigations to bolster our understanding of how educating researchers on broader impacts and societal benefits of their research changes their communication over time. Initially, it does seem that those who learned about communicating impacts tended to display an improvement in their future communications. These findings also indicate a need to further understand differences between senior and early career scholars in the way they communicate broader impacts in their research.

How Are Broader Impacts Communicated?

What are some examples of the broader impacts and societal benefits of your research? Participants reported a breadth of exemplary broader impacts and societal benefits related to their engineering research. By far, improvements to organ transplant accessibility was the most emphasized societal benefit of the engineering research project's work. There were additional general impacts to healthcare that researchers discussed, such as better patient and practitioner outcomes, but transplant accessibility was highlighted in the majority of responses. Since healthcare is generally touted as one of the three main spaces benefitting from the engineering research project’s broader impacts, it is clear that the main impact on healthcare is seen as related to organ transplantation by researchers.

Surprisingly, advancing knowledge in external related fields of research stood out as another primary exemplar of the broader impact of research in the engineering research project. This is not a broader impact that is frequently mentioned within the engineering research project or in how the project describes the effect of its research. Researchers reported that their work directly allows for advancing research in other fields that would otherwise be impossible or take extended timescales to achieve, or that it allows for increased scale of ongoing research. The broad range of external fields that researchers reported, from biosecurity to space travel, illustrated the far reaching and complex ways that the engineering research project’s work does and will continue to impact the world. Responses that mentioned further development of engineering knowledge as a broader impact provided additional context that advancements in the engineering field itself were also deemed as an important example of the benefit of the project’s research.

Respondents also highlighted biodiversity conservation, one of the three pre-identified benefits of the engineering research project's work, but not to the degree that advancing knowledge and increasing transplant access were discussed. Financial considerations, such as gaining additional resources to support engineering, reducing costs of research techniques, and optimizing commercialization processes, were similarly highlighted as an impact of the project research. Some respondents also emphasized that a broader and societal impact of engineering research is in the training of a representationally diverse engineering workforce, though not one of the three pre-identified categories, it is an encouraging finding that indicates researchers are considering the factors that we emphasize in the project interventions around societal benefits.

Finally, food sustainability, general benefits to environmental considerations, and public awareness and interest in STEM, were the three least emphasized themes in responses. Though food sustainability is one of the three highlighted impacts of the project's research, it did not appear to be as relevant to respondents as the organ transplant and knowledge development themes.

Why does the project encourage you to include broader impacts and societal benefits in your research outputs? Participants also shared the reasons for communicating these benefits in their research outputs. It was interesting to compare responses to the reasons provided in the project interventions to educate our researchers. Researchers had additional perspectives on why to include broader impacts and societal benefits outside of the potential increase to representational diversity in the STEM workforce, which was the least emphasized theme in responses.

The main theme respondents shared as to why they communicate the broader impacts and societal benefits in research outputs was their consideration of the practical applicability of research. Though the project research itself spans a wide range of engineering approaches and techniques, it was clear that across all spaces, the importance of shaping how the research being conducted can be practically and effectively applied to problems of the real world was the main reason to consider broader impacts of research in the first place.

Ensuring that research applications truly addressed societal needs was also related to responses emphasizing the influence on the overall direction of research, guiding objectives and increasing or maintaining financial resource allocation based on the relevance of the application of technological and research advancements. Considering ethical concerns specifically in the context of these real world problems, was a related theme respondents deemed as an important reason to include societal benefits in their research outputs. Lesser highlighted themes of motivating the continued future research in engineering, and the general increase in research value of engineering as a result of communicating broader impacts and societal benefits, were observed. These themes were seen as contributing to the overall consideration of how the project research is relevant to current global progress in engineering and overall applicability of its research.

Increased general and public interest and awareness was another main theme in respondents' reasons for including broader and societal impacts in their research outputs. That is, allowing those outside of engineering spaces to increase their understanding of not only the research itself but also the direct impact on society that the research has. Respondents also emphasized that this increased awareness has an additional broader impact of influencing the

funding and resources allocated to this research across funding agencies. These themes were reported as interconnected since interest and awareness were seen as influencing funding priorities by respondents and that this influence on funding is an important reason to communicate broader and societal impacts as well.

Overall, the qualitative analysis allowed for a richer understanding of what researchers see as the primary examples of the broader impacts of the project research outside of the main three that the project emphasizes in its internal communications. We also gained improved perspectives on why researchers include these impacts and benefits in their research outputs. This insight can help us build interventions that support this communication of impacts and benefits that speaks to the priorities of the researchers themselves, while also educating them on the many reasons that their communication of these impacts is important.

Scholarly Significance

The main significance of this work is in learning how to improve STEM researchers' communication and emphasis on broader impacts and societal benefits of their engineering research. This aim serves to support efforts to reach diverse communities of underrepresented minority students and improve representational diversity of engineering research and research in all STEM fields. The current quantitative findings show how researchers are communicating broader impacts and societal benefits of their research over time. Promising effects of educating researchers how to communicate broader impacts and societal benefits of their work were observed in increased numbers of references to these impacts in subsequent presentations. Diverging findings between faculty and trainees indicates a need to continue this research to better understand differences between senior and early career scholars in the way they communicate the broader impacts and societal benefits of their research.

Our qualitative analysis also served as a window into what societal benefits of the engineering research project are actually shared by the researchers themselves, as compared to the engineering research project-emphasized benefits. We were able to better understand what researchers view as the reasons for communicating these benefits in their research outputs. This will allow us to consider any potential barriers to communicating these broader impacts and societal benefits of scientific research. If these barriers can be identified, we can then work to address the mitigation of those barriers such that our community is better informed and supported in their communication of the broader impacts and societal benefits of their research in engineering. Further interventions in our research community may be centered around creating a shared understanding of the considerations that motivate scientists to include broader impacts and societal benefits in their research outputs to then prioritize initiatives that facilitate those motivating factors. With continued research in this space, we can continue to support diversity of research through imparting the meaningfulness of research to URM students.

References

Allen, M. J., Muragishi, G. A., Smith, J. L., Thoman, D. B., Brown, E. R. (2015). To grab and hold: cultivating communal goals to overcome cultural and structural barriers in first-generation college student's science interest. *Transl Issues Psychol Sci, 1*, 331–341.

Azungah, T. (2018), "Qualitative research: deductive and inductive approaches to data analysis", *Qualitative Research Journal*, Vol. 18 No. 4, pp. 383-400. https://doi.org/10.1108/QRJ-D-18-00035

Estrada, M., Burnett, M., Campbell, A. G., Campbell, P. B., Denetclaw, W. F., Gutiérrez, C. G., Hurtado, S., John, G. H., Matsui, J., McGee, R., Okpodu, C. M., Joan Robinson, T., Summers, M. F., Werner-Washburne, M., & Zavala, M. E. (2016). Improving underrepresented minority student persistence in stem. *CBE Life Sciences Education, 15*(3), 1–. https://doi.org/10.1187/cbe.16-01-0038

Freeman, R., Huang, W. (2014) Collaboration: Strength in diversity. *Nature 513*(305). https://doi.org/10.1038/513305a

Miller, P. H., Rosser, S.V., Benigno, J.P., Zieseniss, M. (2000). A desire to help others:goals of high achieving female science undergraduates. *Women Stud Q, 28*(1–2), 128–142.

National Science Foundation. (2024). *Diversity and STEM: Women, Minorities, and Persons with Disabilities*. U.S. National Science Foundation. https://ncses.nsf.gov/pubs/nsf23315/faqs

Ogbogu, U., & Ahmed, N. (2022). Ethical, legal, and social implications (ELSI) research: Methods and approaches. *Current Protocols, 2*, e354. doi: 10.1002/cpz1.354

Seymour, E., Hewitt, N. (1994). *Talking about leaving: Factors contributing to high attrition rates among science, mathematics, and engineering undergraduate majors.* Boulder, CO: Ethnography and Assessment Research, Bureau of Sociological Research.

Thomas, D. R. (2006). A General Inductive Approach for Analyzing Qualitative Evaluation Data. *American Journal of Evaluation*, *27*(2), 237-246. https://doi.org/10.1177/1098214005283748

Wigfield, A., Tonks, S., Klauda, S. L. (2009). *Expectancy-value theory*. In: Handbook of Motivation in School, ed. Wentzel, K. R., & Wigfield, A. New York: Routledge, 55–76.

Xiang, P., McBride, R., Guan, J., Solmon, M. (2003). Children's motivation in elementary physical education: an expectancy-value model of achievement choice. *Res Q Exerc Sport 74*, 25–35.

Figure 1.

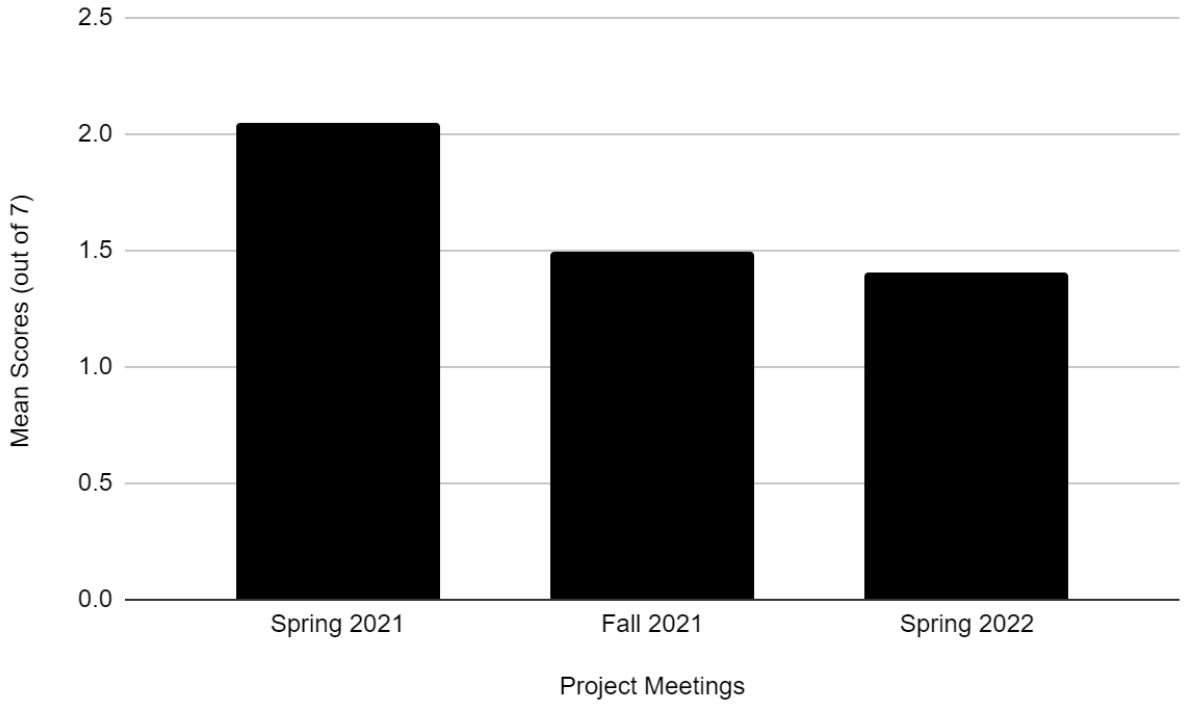

Figure 1: Mean Broader Impacts and Societal Benefits Scores. Mean scores across all project members over time.

Figure 2.

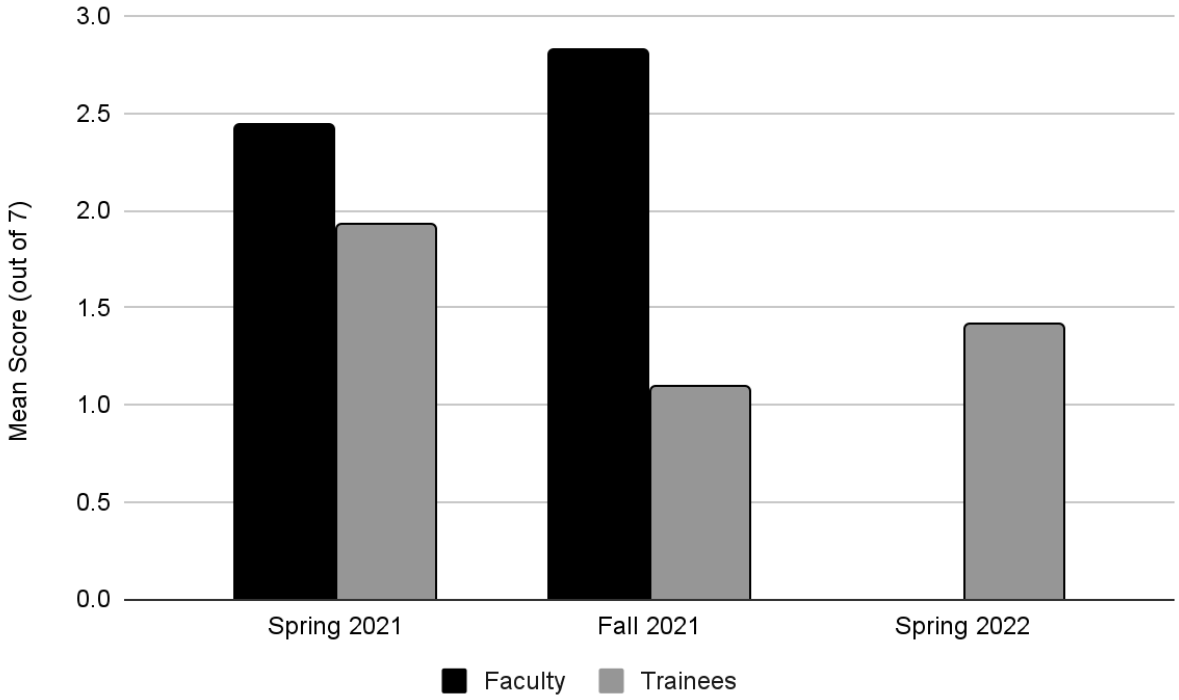

Figure 2: Mean Broader Impacts and Societal Benefits Scores. Comparison of mean scores by role over time, specifically faculty and trainee (undergraduate, graduate students, research staff/technicians, and postdoctoral researchers) project members.

Figure 3.

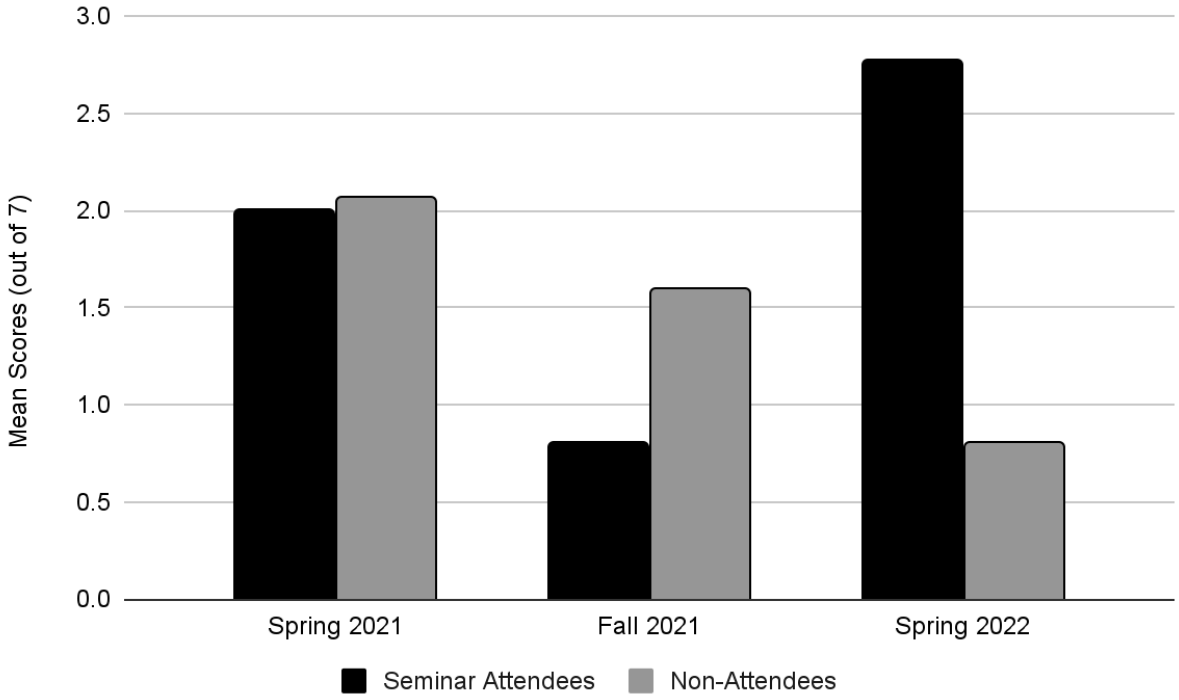

Figure 3: Mean Broader Impacts and Societal Benefits Scores of Seminar Attendees and Non-Attendees. Comparison of mean scores for seminar attendees and non-attendees over time.

Table 1.

Broader and Societal Impact Category	**Referenced in Presentation?**	**Examples**
Broader Impacts	(Yes / No)	“Access to biological tissues that make people's lives better”
Societal Impacts	(Yes / No)	“protect threatened or critically endangered wild populations for improved food security domestic and abroad.”
Diversity	(Yes / No)	“Increasing Women and URM representation to meet biomedical workforce needs”
Culture	(Yes / No)	“Providing guidance on establishing an inclusive culture through training, resources, policies, and trainings”
Inclusion	(Yes / No)	“Increasing STEM identity involves increased feelings of inclusion and belonging (value) in STEM fields”
Equity	(Yes / No)	“equitable access of tissues, organs, etc.”
Ethics	(Yes / No)	“Pig hearts used as ethical models for human cardiac output after a myocardial infarction”
Total (out of 7):	(minimum: 0, maximum: 7)	

Table 1: Presentation Societal Impact Coding Rubric. Coding of research presentations for broader and societal impact references. Each presenter was given a total sum score out of seven for the number of categories they included in their presentation.

Table 2.

Project Member Role	In the course of your research, do you feel that you are considering societal issues– the potential risks and benefits to Society? (YES or NO)	In the course of your research do you feel that you are considering challenges facing diverse, underserved Populations? (YES or NO)	In the course of doing your research does your lab explicitly discuss ethics? (YES or NO)
Faculty (N = 10)	90% YES	90% YES	90% YES
Trainees (N = 16)	94% YES	63% YES	44% YES

Table 2: "Pulse" Survey Responses. Comparison of survey responses by project member roles.