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Sparking shifts in STEM: Facilitating equitable change through workshops on emerging and understudied research questions

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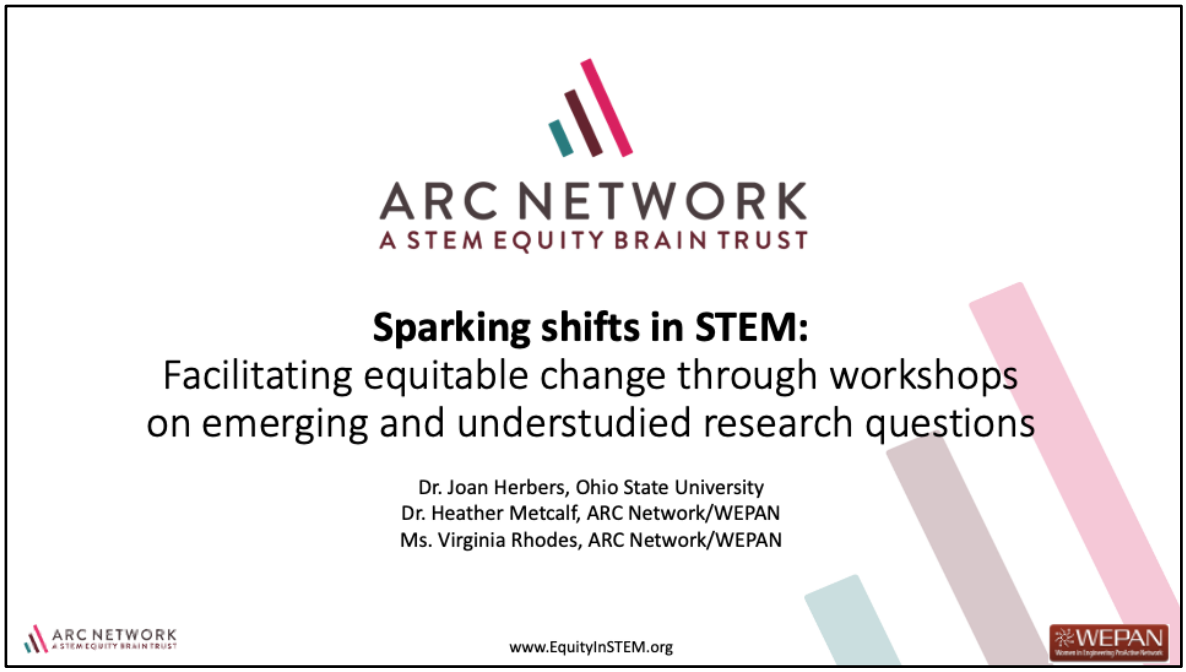
Heather Metcalf, PhD, is the Director of Research for the Women in Engineering ProActive Network (WEPAN). She serves as an investigator on several NSF-funded initiatives including the ADVANCE Resource and Coordination (ARC) Network, which focuses on gender equity in academic STEM through an inclusive, intentional, and intersectional lens; Amplifying the Alliance to Catalyze Change for Equity in STEM Success (ACCESS+), which cultivates gender equity across all of the activities of STEM professional societies; the ADVANCE and INCLUDES I-Corps Inclusion Collective, which aims to create more equitable and inclusive I-Corps programs; the New Jersey Equity in Commercialization Collective, which works with technology transfer offices and investors across the state of New Jersey to build a more diverse, equitable, and inclusive commercialization ecosystem; and the Commemorating 20 Years of ADVANCE: Design Thinking Sessions for a Digital Exhibit and Archive project. She is also PI for the WEPAN Accelerator, an entrepreneurship accelerator program for women in engineering funded by the Small Business Administration.

Prior to joining WEPAN, Dr. Metcalf did her postdoctoral research at the University of Arizona as part of their NSF ADVANCE Institutional Transformation grant and was Chief Research Officer at the Association for Women in Science (AWIS). Dr. Metcalf has undergraduate degrees in applied mathematics and computer science from Clarion University of Pennsylvania, master's degrees in computer science from the University of Illinois at Urbana-Champaign and gender studies from the University of Arizona, and a doctorate in higher education, science, and technology policy from the University of Arizona.

Virginia L Rhodes M.S., The Women in Engineering ProActive Network (WEPAN)

Virginia Rhodes is the ADVANCE Resource and Coordination (ARC) Network Project Director, one of the initiatives of the Women in Engineering ProActive Network (WEPAN). She is passionate about advancing the culture of inclusion and diversity within STEM disciplines, and her background and experience in the social sciences and the broader ADVANCE community has allowed her to utilized her research expertise and put that knowledge into practice. She applies psychological concepts and interventions to address gender and racial disparities throughout multiple STEM fields. She becomes most excited about creating change related to diversity, equity, and inclusion, and strives to build more intersectional and informed communities of practice.



The ARC Network has two research goals: one is to recruit, fund, and oversee Virtual Visiting Scholars and the other is the facilitate Emerging Research Workshops which this presentation is focused on.

The Research Advisory Board (RAB) of the ARC Network identifies the themes for the Emerging Research Workshops as primary areas in need of further research exploration and/or intervention in academic science, technology, engineering, and mathematics (STEM) workplaces. The RAB decides the themes based on recent scholarship, interests of the community, and current events. For example, the RAB selected the 2019 theme of identity-based harassment given a combination of new reports on sex- and gender- based harassment released by the National Academies, the #MeToo movement, and the dearth of literature considering harassment from an intersectional perspective, for example, by looking at gender-based harassment in tandem and intertwined with race-based harassment rather than in isolation from one another.

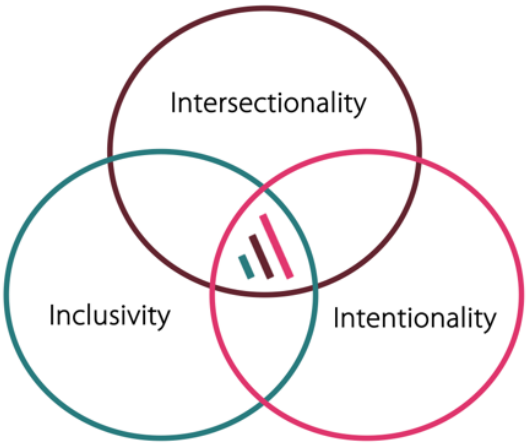
About the ARC Network

Funded by the National Science Foundation ADVANCE Program, Awards HRD-2121468 and HRD-1740860, the ADVANCE Resource and Coordination (ARC) Network seeks to promote systemic change and intersectional gender equity for STEM faculty.

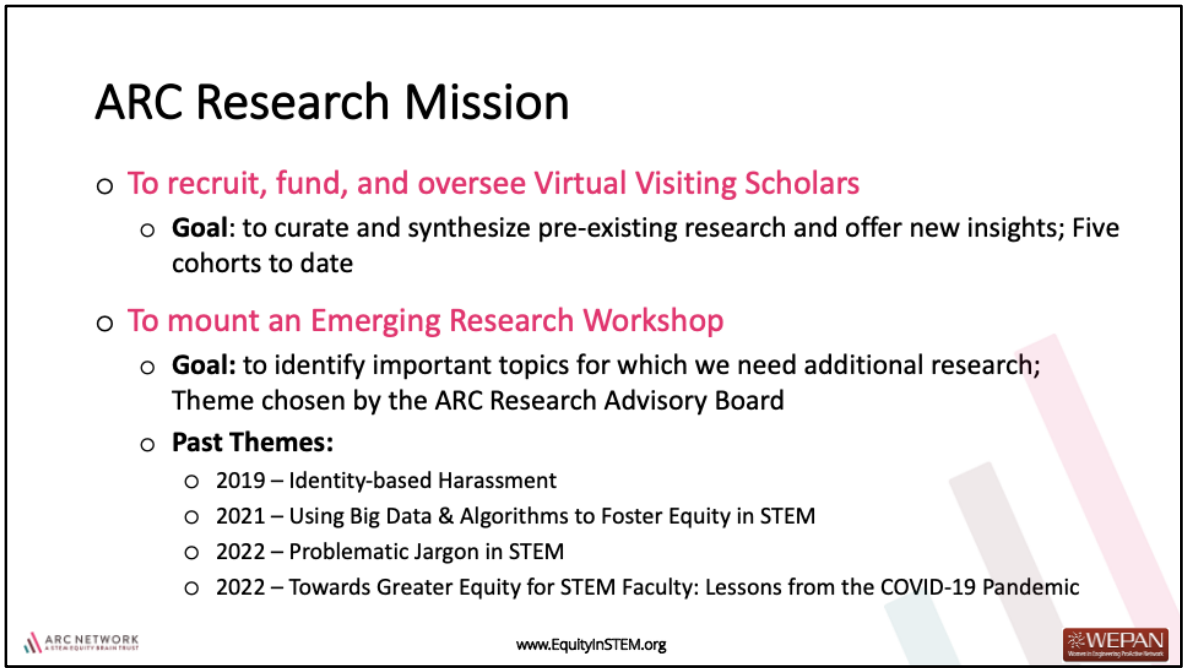
As the STEM equity brain trust, the ARC Network works to remove barriers to resources, advance the research on intersectional gender equity issues, and reduce duplication of efforts.

The Women in Engineering ProActive Network (WEPAN) serves as the organizational home for the ARC Network.

ARC Network Mission



The ARC Network strives to enable authentic, intentional dialogue between researchers and practitioners, connect inclusiveness to organizational principles and practices, and account for and incorporate intersectional perspectives throughout our work.



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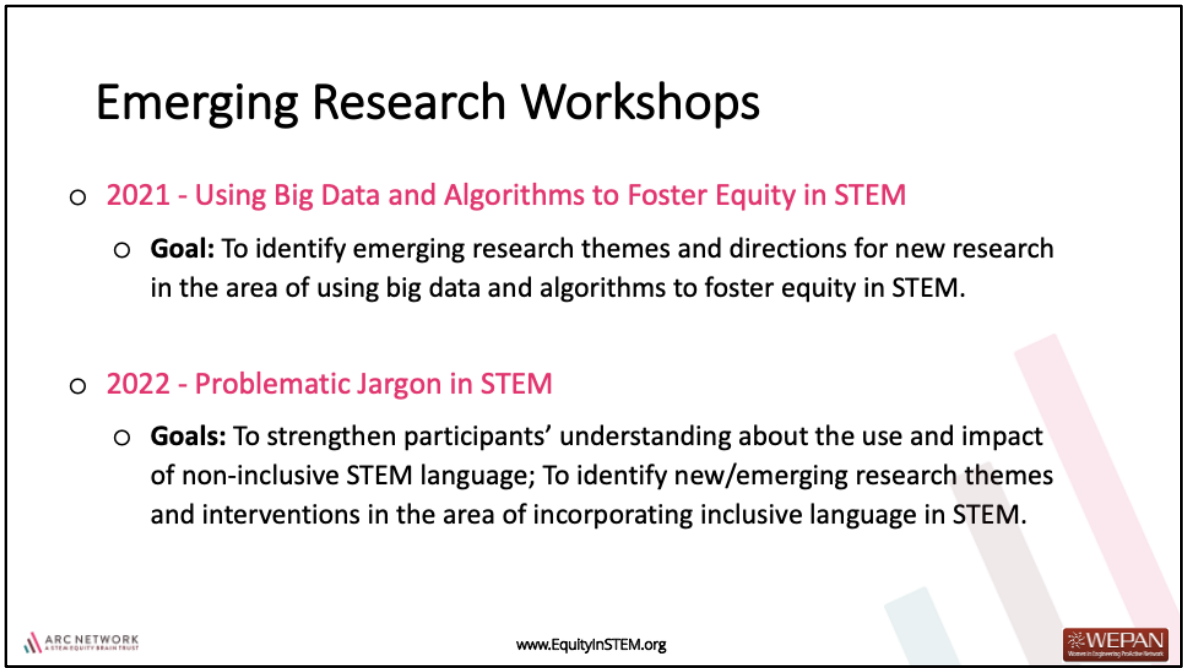
These two-day workshops are designed to engage participants in facilitated discussions on current research and practice, identify areas of synergy and unanswered questions, and then prioritize where additional or new research, policy, and/or intervention are needed.

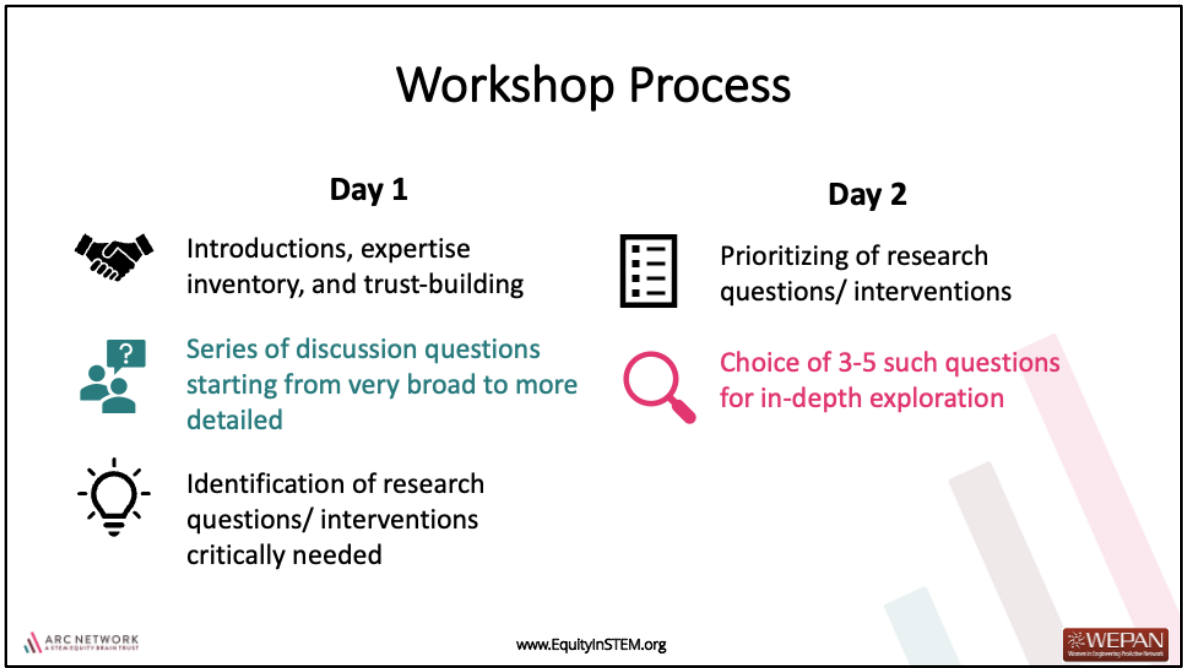
A planning committee composed of scholars and practitioners who do work in the respective research areas is appointed by the ARC Network PIs and is responsible for developing a workshop agenda, identifying relevant background materials, and curating a list of potential invitees. Members of the workshop planning committee nominate scholars working in the respective area who represent a diverse array of disciplines, research specialties, institution types, career stages, and social demographic backgrounds. Each workshop has between 20-30 attendees. During the initial planning and throughout the workshop, we use an intersectional gender equity framework and build space such that multiple perspectives are heard.

At the conclusion of the workshop, a concept paper comprised of everything discussed is then given to the participants and ARC community for feedback before being published for the broader community, including researchers, administrators, change

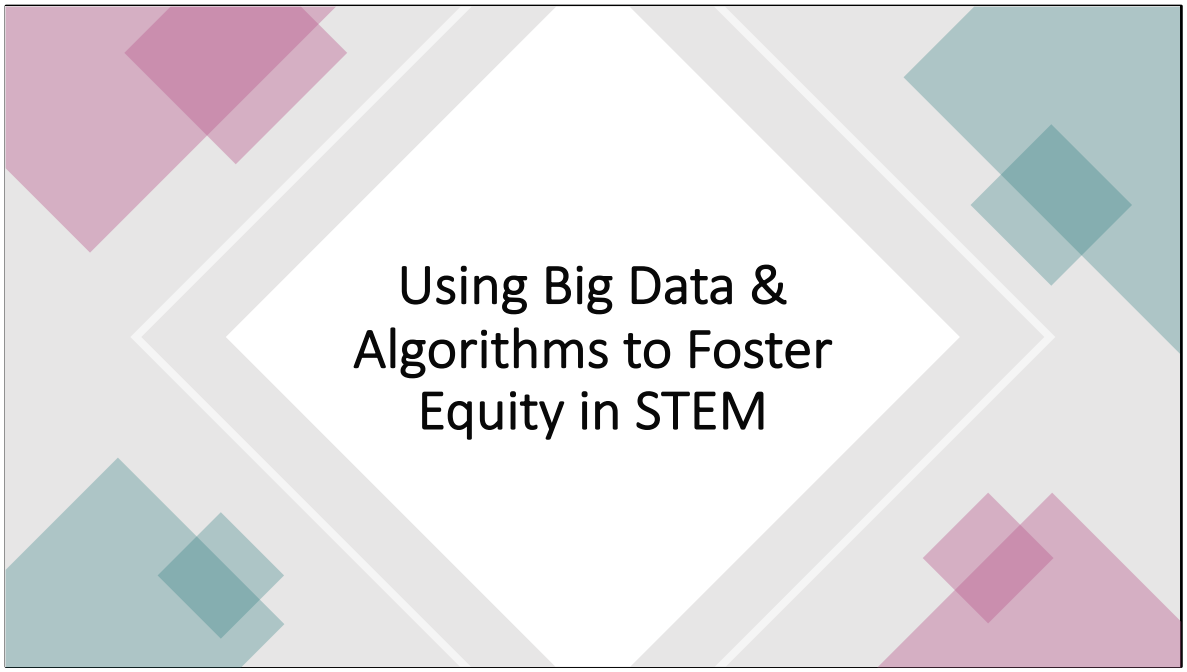
makers, and funding agencies. Participants are encouraged to continue research and collaborate beyond the workshop as well.

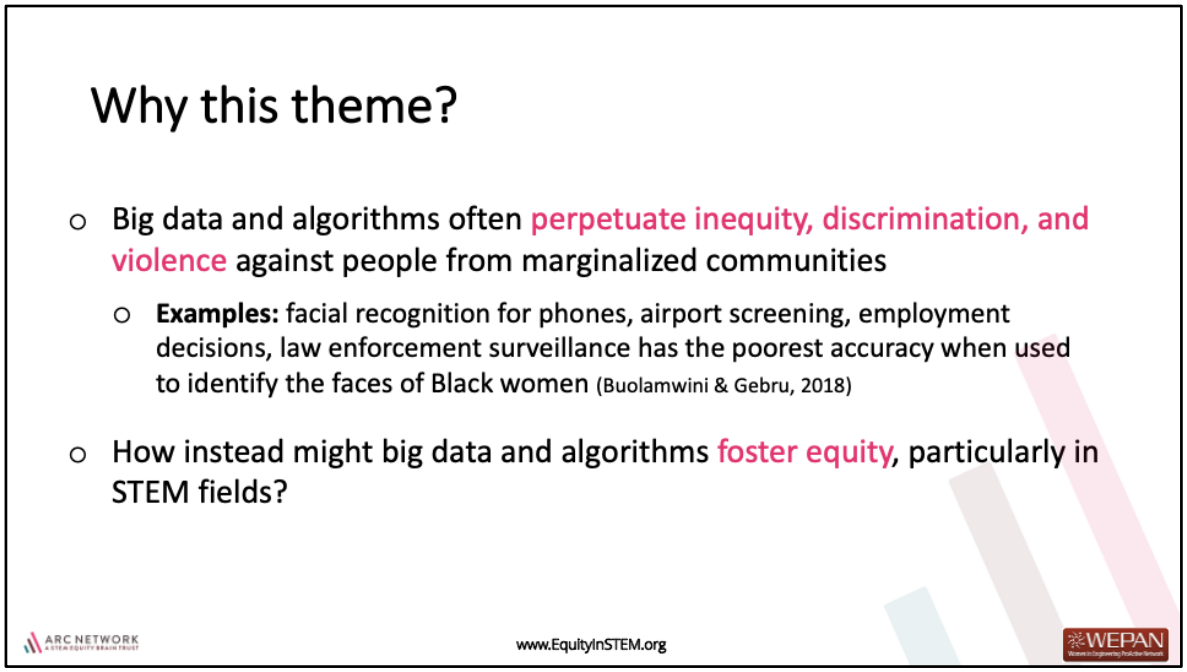


This presentation will focus on two of our workshops: Using Big Data and Algorithms to Foster Equity in STEM and Problematic Jargon in STEM.

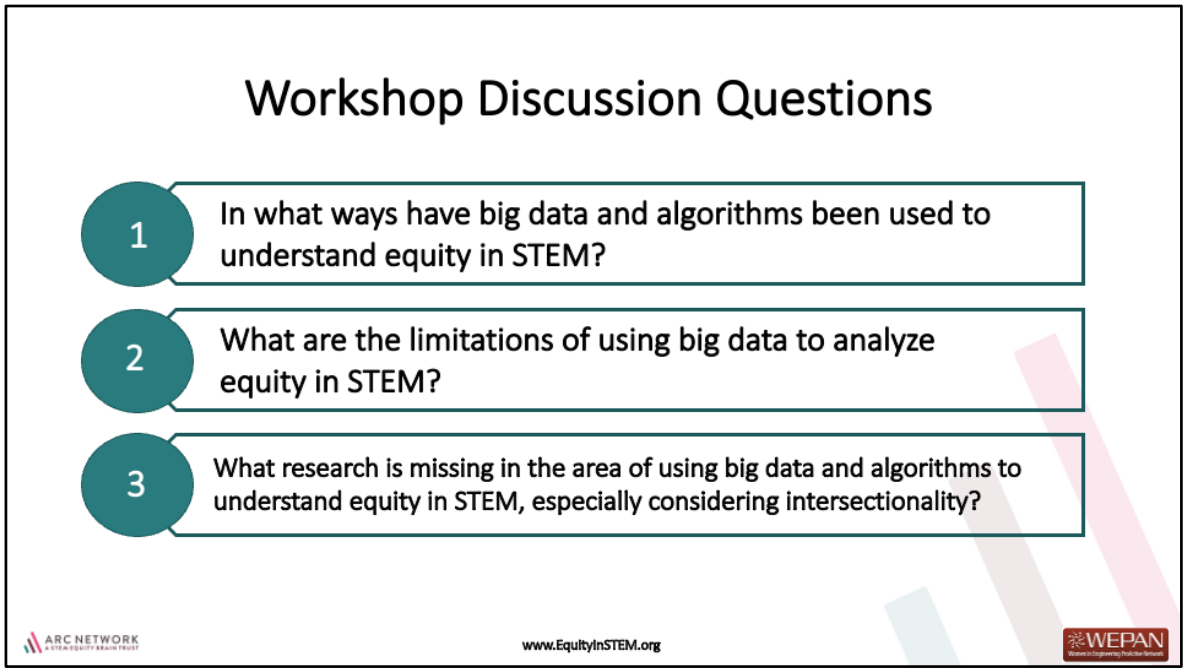


This is the process we followed across the two days. For the two workshops that'll be discussed during this presentation, I'll walk you through the discussion questions attendees were guided through and the resulting priority research questions or interventions that were identified.


Using Big Data &
Algorithms to Foster
Equity in STEM

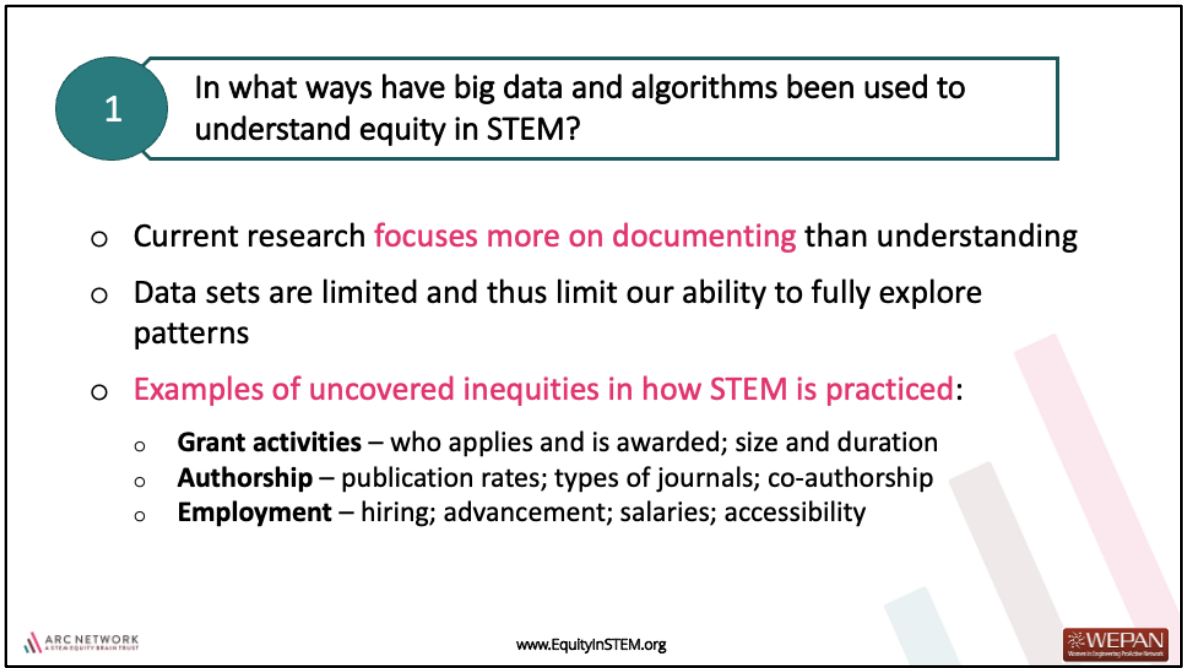


This theme was selected because of the ways in which big data and algorithms often perpetuate inequity, discrimination, and violence against people from marginalized communities. For example, facial recognition software used to unlock cell phones , for airport passenger screening, in employment decisions, and for law enforcement surveillance not only raises privacy issues, but also dangerously and consistently has the poorest accuracy when used to identify the faces of Black women (Buolamwini & Gebru, 2018). This is a problem not because we want the tech to work, but because those with marginalized identities are disproportionately targeted. At the workshop, the planning committee sought to discuss how big data and algorithms might instead *foster* equity, particularly in STEM fields.



To answer this question (see end of previous slide), workshop participants engaged in small-group discussions on a series of guiding questions centering intersectional gender equity in STEM:

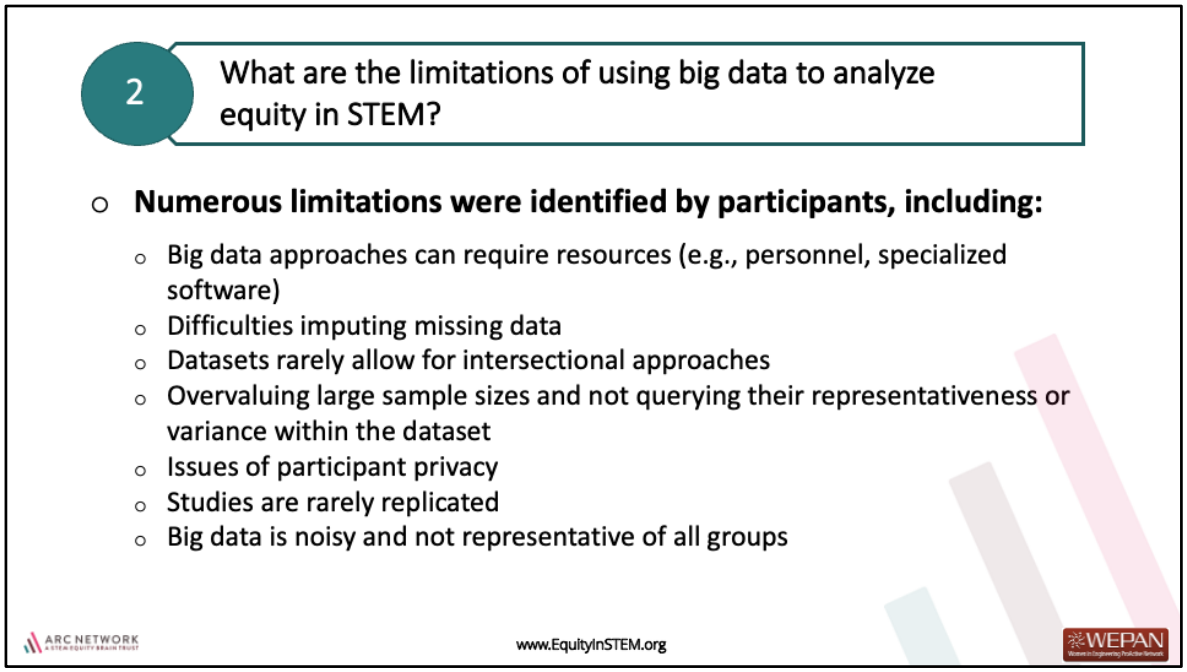
1. In what ways have big data and algorithms been used to understand equity in STEM?
2. What are the limitations of using big data to analyze equity in STEM?
3. What research is missing in the area of using big data and algorithms to understand equity in STEM, especially considering intersectionality?



It is important to realize that current research focuses more on *documenting* or *predicting* than *understanding*; big data and algorithm analysis have uncovered patterns of inequity in STEM but are not always able to explain how those patterns arose nor how to ameliorate them. Datasets are themselves limited and thus limit our ability to fully explore patterns.

That said, studies using a variety of data sources (e.g., administrative data, text and publication data, network data, patent records, etc.) have uncovered inequities in how STEM is practiced, including:

- Grant activities: who applies for and is awarded grants; grant size and duration; individual versus group grants
- Authorship: publication rates, types of journals, co-authorship, author rank
- Letters of recommendation: language used, length
- Student evaluations: differential language used by students and professor ratings
- Citations: who is cited, self-citations
- Computer simulations: accumulation of disadvantage across a STEM career
- Request for extensions: grant submissions, applications
- Employment: hiring, advancement, salaries, resource allocation, accessibility
- Innovation and commercialization: patenting activities
- Algorithms and machine learning: interview software, resume readers, surveillance software
- Imputation: imputing characteristics of individuals and groups
- Dashboards for decision-making: dashboards for executives; tools and technology that are made that end up in administrative buildings

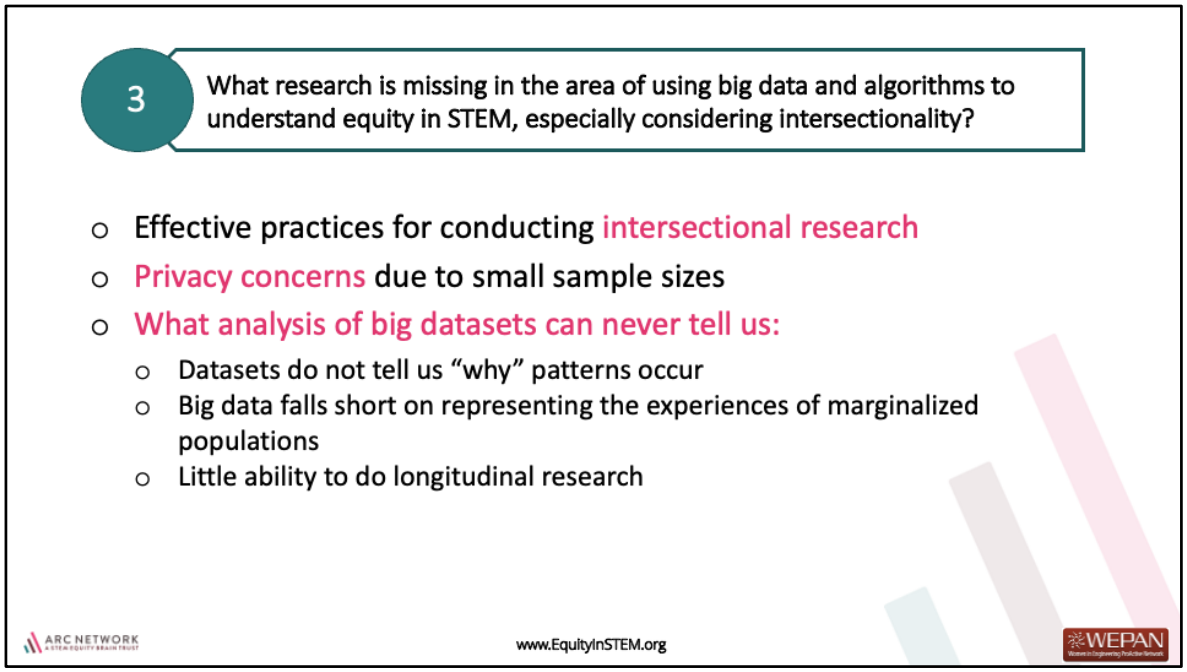


Several limitations were identified by participants:

- Big data approaches can require resources (e.g., costs of buying datasets, specialized software to mine data, personnel)
- Holes exist in most big datasets (missing variables, missing values); this is related, in part, to the concept of data exhaust
- Biases exist in some datasets; for example, census data under-represent individuals from skeptical of fearful groups who are more likely to be undocumented
- Difficulties of imputing missing data: gender is a

social constructed variable, not a biological one, and using first names to impute gender according to a binary introduces errors; variables concerning race rarely allow for mixed-race identifications

- Foreign nationals, who comprise the majority of graduate students and postdocs in many STEM fields, are usually omitted
- Data sets rarely allow for intersectional analysis
- Scientists overvalue large sample sizes and do not always query their representativeness
- Data sets that are available are rarely collected for the purposes to which researchers what to use them
- Issues of participant privacy
- Qualitative research may be marginalized
- Studies are rarely replicated
- Results cannot help us understand the behavior of or impact on individuals
- Big data is noisy and not representative of all groups
- Ineffective, if any, methods to detect and quantify bias in data sets

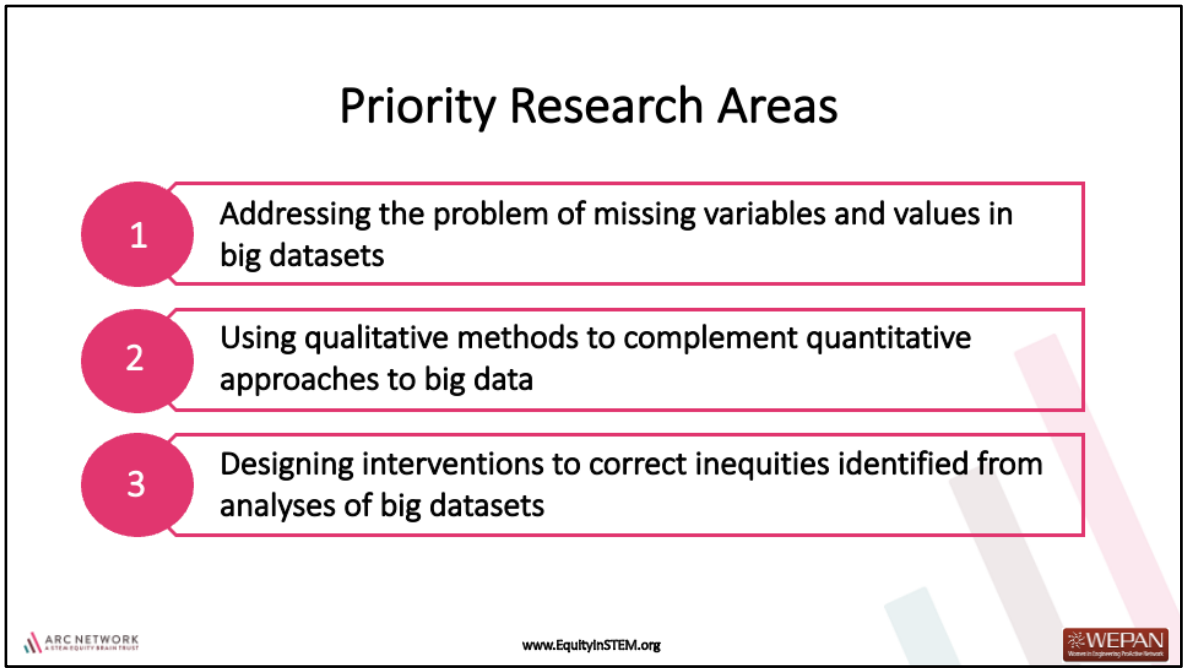


Participants engaged in a very lively discussion around what research is missing and while I can't cover everything that was discussed, I'd like to share a few of the key points.

- With regard to intersectional research and datasets the questions raised were how can we structure data to address intersectionality questions? How can we use multiple datasets/ merge data sets to identify missing values and improve intersectional collection and analysis?
- Privacy issues: intersectional studies can result in small

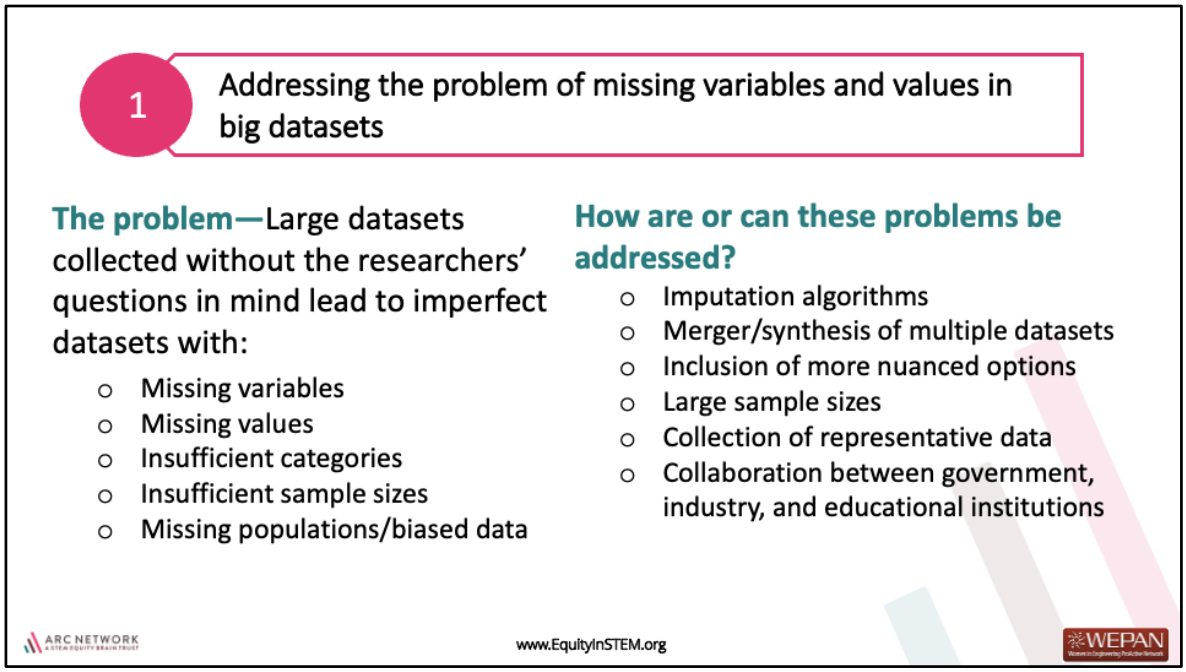
sample sizes, producing concerns for privacy. Members of very small groups might be easily identifiable.

- What can big data studies tell us about: the implications for policy and effectiveness of interventions? Or about the cultures of different disciplines?
- What analysis of big data sets can never tell us:
  - We can measure publications, citations, authorship, etc. but they are at best proxies for knowledge generation and impact
  - We know that individuals from marginalized groups self-select out of careers n STEM at higher rates , but the datasets do not tell us why
  - Marginalized populations will have small sample sizes, and big data falls short in enlightening us about their experiences
  - Big data sets are snapshots, with little ability to do longitudinal research (with newer datasets having to match the old ones to successfully do longitudinal research, otherwise we encounter the same imputation/inference problem discussed earlier).



After discussion, participants showed a strong interest in further developing three priority research areas:

1. Addressing the problem of missing variables and values in big datasets
2. The need for qualitative methods to complement quantitative approaches
3. The desire to design interventions to correct inequities identified from analysis of big datasets



The central research question we considered: How can we improve the infrastructure of datasets and remedy missing variables/values/populations?

The problem: Most large datasets used by researchers were not collected with the researchers' questions in mind. These imperfect datasets suffer from problems including:

1. Missing variables (e.g., ethnicity, ability status)

2. Missing values

3. Variables with insufficient categories (e.g., binary gender choices, mixed-race classification)

4. Insufficient sample sizes to allow for intersectional questions

5. Missing populations/biased data (e.g., foreign nationals, nonbinary individuals)

There are two principal methods researchers use to fill in the gaps of missing variables or values:

1. Imputation algorithms that use machine learning to guess missing variables/values
2. Merger/synthesis of multiple datasets

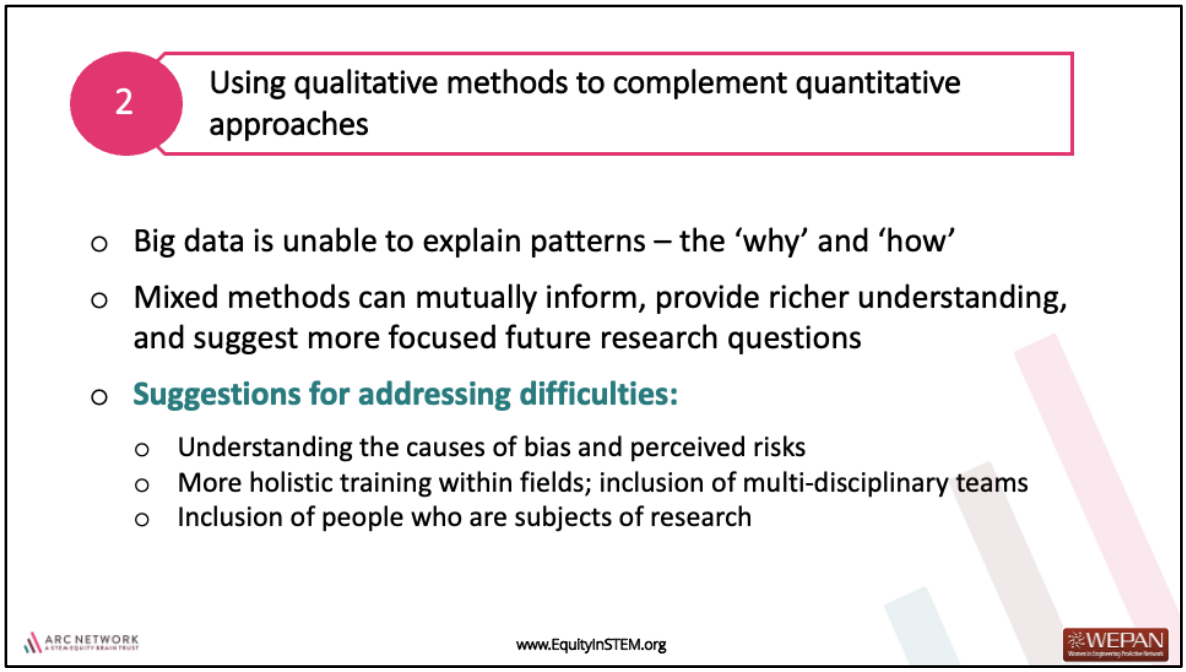
Problems 3-5 can only be addressed by interacting with those originally involved in the research:

1. Included more nuanced options. For example, a mixed-race option for self-identified ethnicity is becoming more common in questionnaires.
2. In order to probe questions concerning intersectional identity, datasets need to have very large sample sizes and/or use stratified sampling methodology.

(Understanding risks perceived by individuals and finding ways to mitigate those risks is key to inclusive sampling)

3. Fully understanding some questions of equity requires collection of data representing *all* who are engaged in the scientific enterprise, not just citizens and those with green cards

Solving the above problems will require collaborations between government, industry, and educational institutes.

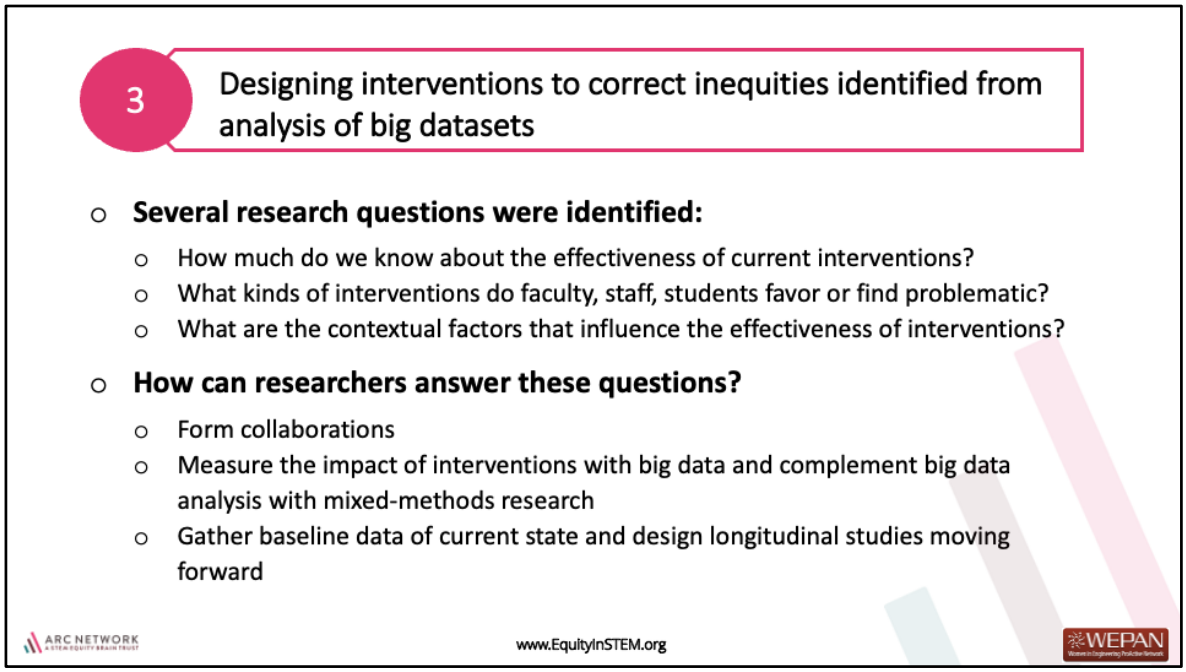


Quantitative data analysis has proven very effective for identifying areas of inequity in STEM (publishing, citations, career progression, patenting, etc.), but big data is limited in its ability to explain the origin and persistence of those patterns., the 'why' and 'how'. While results from analyzing big datasets have been readily accepted, their limited explanatory power means we must use supplemental/additional research methods to understand and address inequities. In other words, qualitative data such as ethnographic information, text, interviews, focus group transcripts, etc.

Qualitative data methods rely on in-depth understanding of individual experiences and extrapolation from those experiences. The use of qualitative methods has allowed us to better understand why, for example, girls lose interest in science in middle school. When quantitative and qualitative methods are used in tandem, they can inform each other, provide richer understanding, and suggest more focused future research questions.

Of course, both methods have their own difficulties. Thus, a deeper bottom-up understanding of the causes of bias and perceived risks from the research participants is essential. There is a strong argument for having multi-disciplinary teams and more holistic training within fields. Lastly, qualitative research often requires collaboration

with groups who represent potential research subjects. The inclusion of people who are subjects of research can greatly improve research methodologies by suggesting fruitful avenues of inquiry and potential sources of bias and error.



While thinking of how to design interventions moving forward, this group began identifying several research questions:

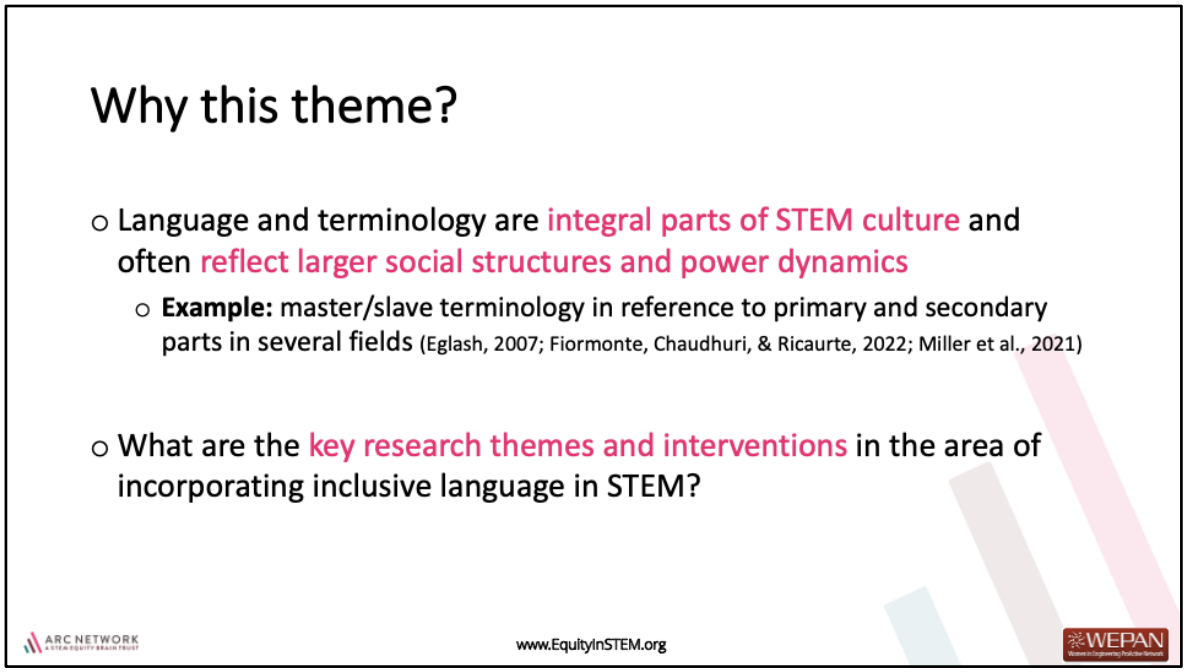
- How much do we know about the effectiveness of interventions that seek to promote equity, and what is big data's role in those inquiries? How can we know more, prior to advancing additional interventions?
- What kinds of interventions do faculty, staff, students favor? Which ones do they find problematic, and why? How do we address conflicting needs across groups?
- How can we assess the internal distribution of resources within institutions for equity? What are the contextual factors that influence the effectiveness of interventions? For example: interventions created for predominantly white institutions (like mentoring program) may not work well at an HBCU.
- For context, as an example, h-indices were suggested some years ago as an alternative to raw citation numbers. They were quickly adopted, but have since been shown to be problematic as well.

Some of the suggested avenues to answer these questions researchers can take are:

- Form collaborations

    - Between interdisciplinary researchers with experience in qualitative methodologies (ethnographic and participatory action research) and quantitative methodologies (big data, survey, algorithms)
    - With communities impacted by marginalization
    - With institutional leadership/gatekeepers (i.e., Institutional data offices)
- Measure the impact of interventions through big data so empirically informed policies will be more efficient with more effective outcomes
- Gather baseline data of current state and design longitudinal studies moving forward

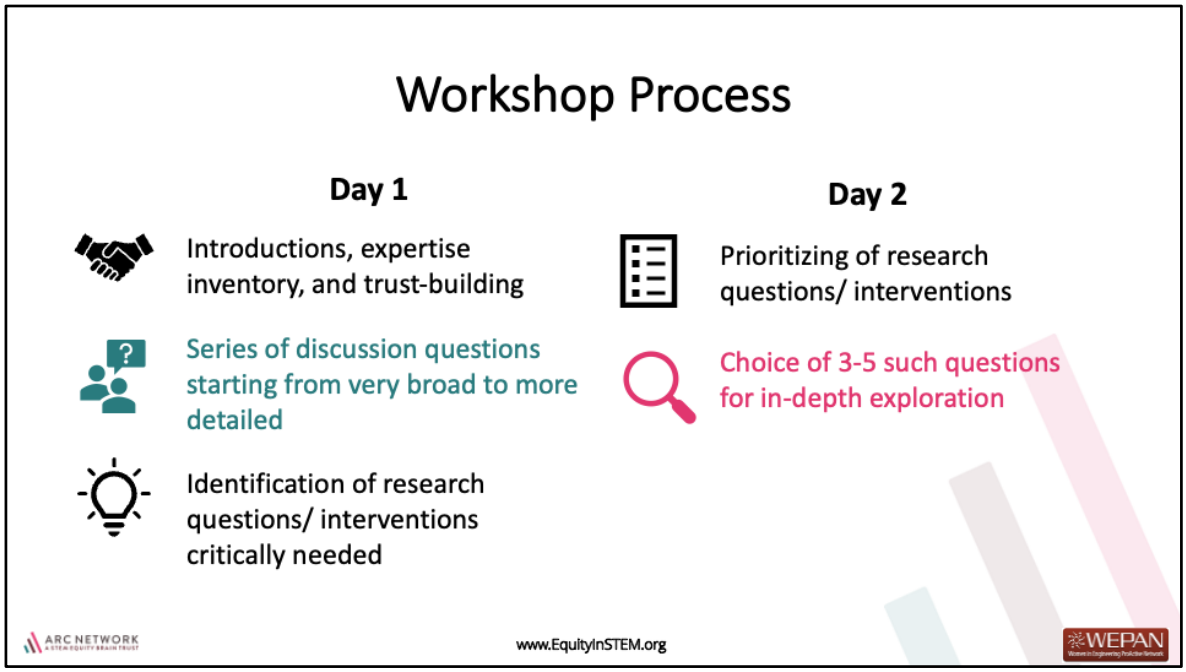
Problematic Jargon in STEM



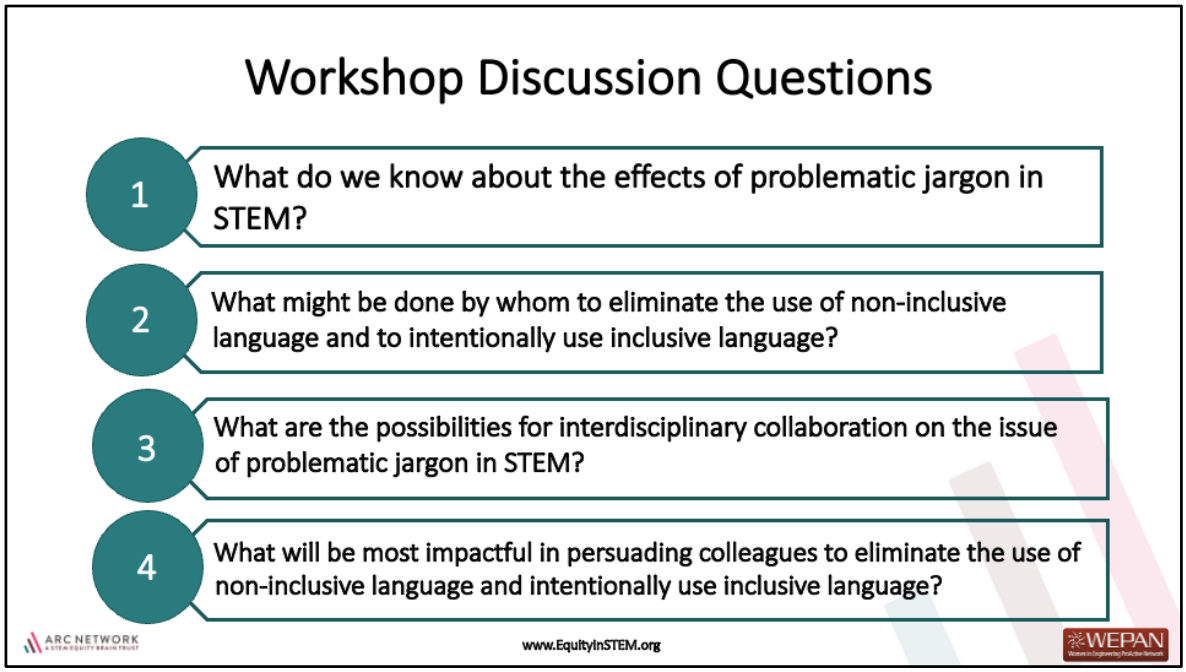
This theme was selected because language and terminology are integral parts of STEM cultureand often reflect larger social structures and power dynamics. The language, rhetoric, metaphors, and key terminology within STEM fields shape accessibility and inclusion in those fields as well research approaches and solutions. For example, in computing, engineering, and technology, the commonly used terminology of master/slave to refer to primary and secondary parts and male/female to refer to “mating” connectors reflect problematic metaphors steeped in white supremacy as well as sexism and heteronormativity (Eglash, 2007; Fiormonte, Chaudhuri,

& Ricaurte, 2022; Miller et al., 2021).

While the previous workshop focused on research avenues, this workshop introduced intervention as well to stop the impact of problematic jargon.



A reminder of the workshop process we followed.



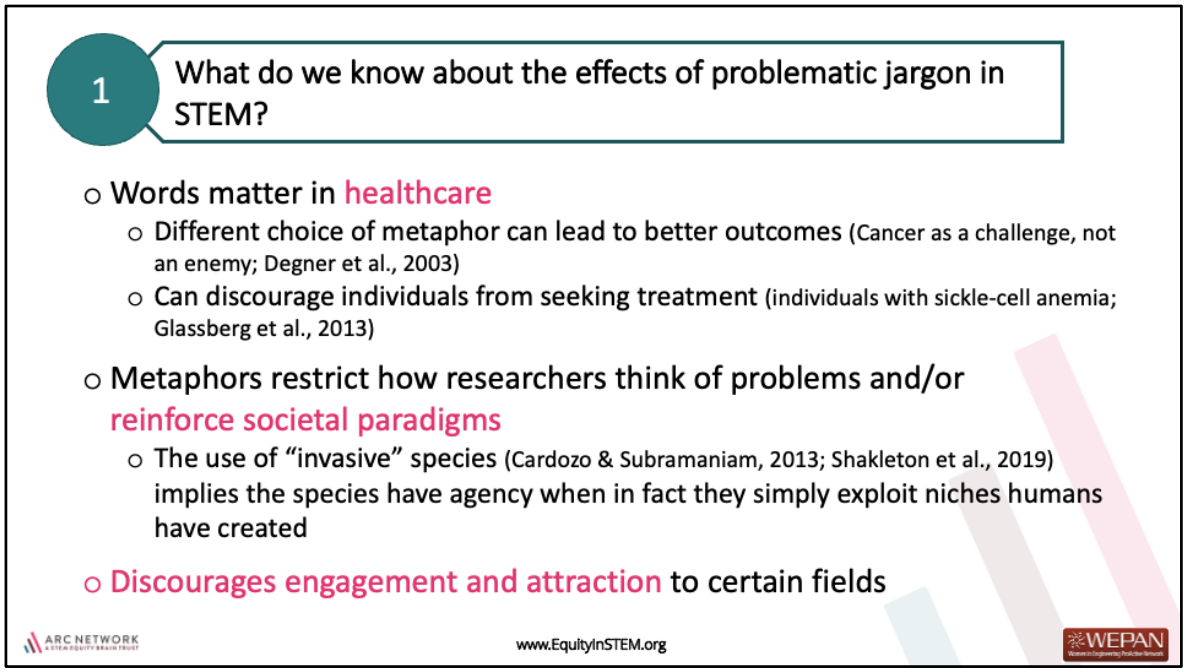
To answer this question (see end of previous slide), workshop participants engaged in small-group discussions on a series of guiding questions:

1. What do we know about the effects of problematic jargon in STEM?

2. What might be done (taught, created, researchers, governed, etc.) and by whom, to eliminate the use of non-inclusive language and to intentionally use inclusive language in STEM?

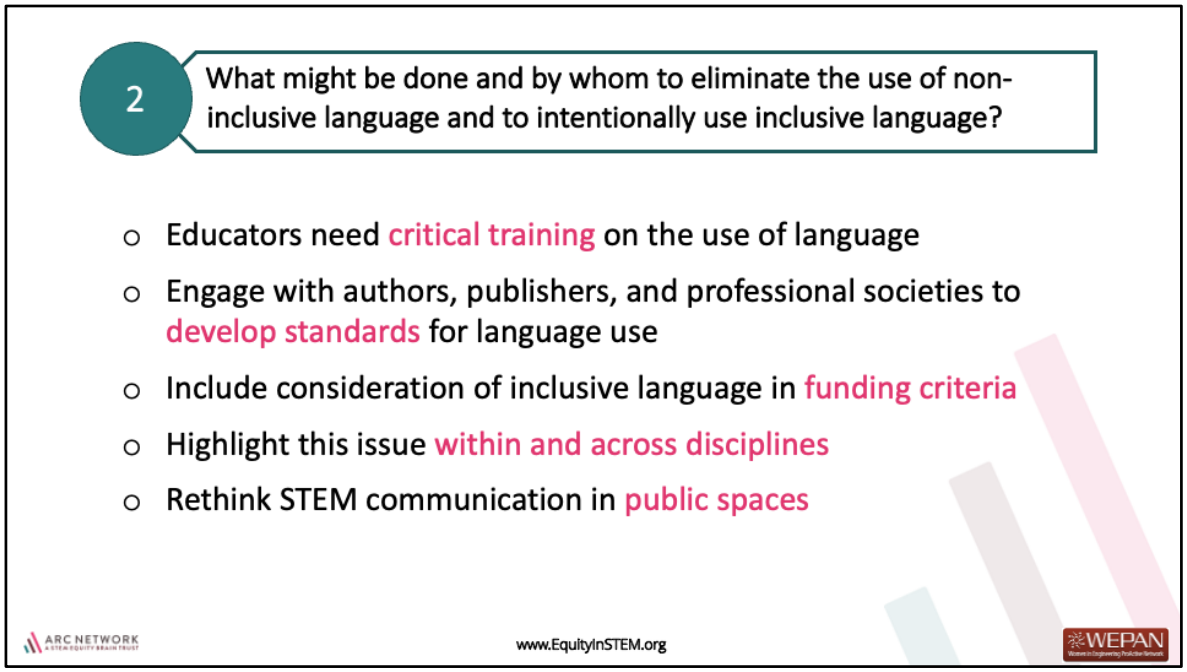
3. What are the possibilities for interdisciplinary collaboration on the issue of problematic jargon in STEM?

4. What do scientists find persuasive? What will be most impactful in persuading colleagues to eliminate the use of non-inclusive language and intentionally use inclusive language? Who are the appropriate people or organizations to engage in this effort?



- In health care, metaphors are essential to patient understanding, and words matter. For example, we know that patients who are told cancer is a challenge rather than an obstacle (or worse, punishment) have better outcomes (Degner et al., 2003). In other cases, the choice of words can discourage individuals from seeking treatment. For example, patients with sickle-cell anemia are called "sicklers" by physicians, who often treat them as difficult and ignorant about their own bodies (Glassberg et al., 2013).
- Usage of metaphor places restrictions on how researchers think about problems. For example, use of "invasive" species implies agency on the part of pests, although many such species simply occupy niches created by human disturbance (Cardozo & Subramaniam, 2013; Shackleton et al., 2019). They are not invaders, but rather opportunists. Furthermore, when a metaphor becomes entrenched it can reinforce societal paradigms, in this case of militarism and xenophobia.
- Use of language that evokes power (e.g., war, frontier, individualism) can discourage engagement by those who do not accept those structures of power. Students in particular may not be attracted to fields that use alienating metaphors (e.g., master and slave systems in engineering). Non-inclusive language limits who is attracted to the field, which further reinforces prevailing paradigms. The

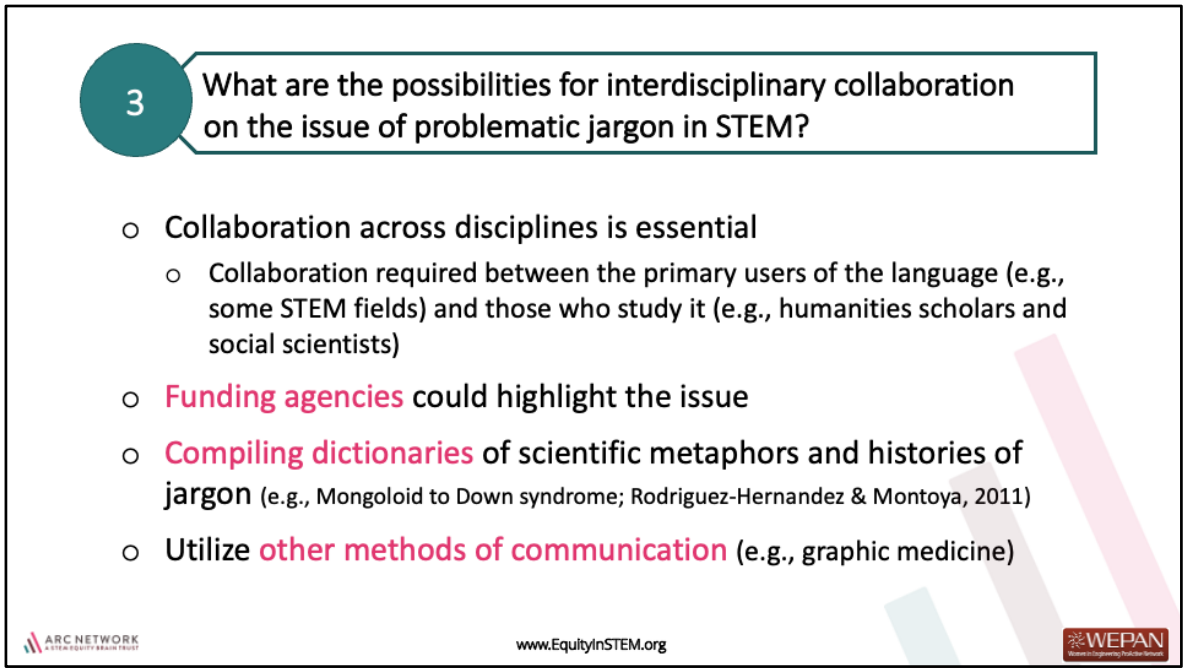
collaborative nature of science is best achieved when multiple perspectives are engaged, and thus use of non-inclusive language limits the community engaged in scientific discourse.



- Educators, present and future, need critical training on the use of language and students should be encouraged to share their experiences. Embedding such training and listening into STEM curricula is necessary to avoid it being perceived as a nicety or political correctness.
- The relative lack of social perspectives in STEM education reflects the tyranny of content over understanding. Professional societies and accreditation bodies have key roles to play in encouraging humanistic/social science perspectives.
- Funding agencies must be alerted to this problem,

and they should include consideration of inclusive language in their criteria.

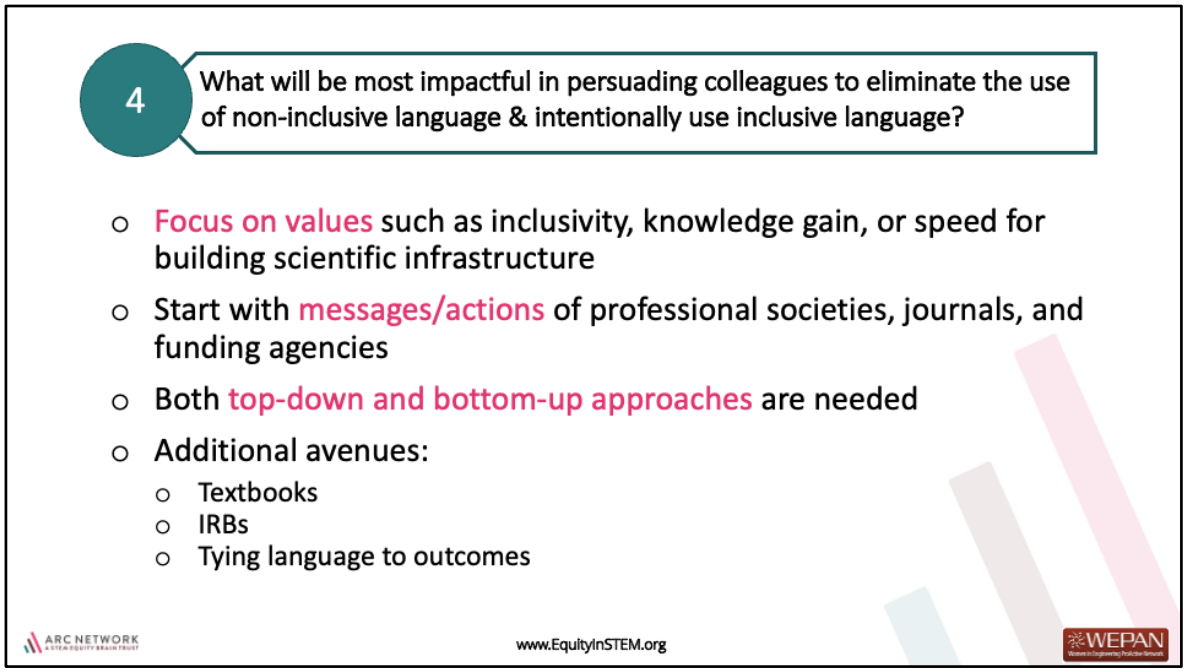
- Highlighting this issue within and across disciplines is important; while one discipline may use a problematic term, there are similarities across disciplines that can make the problem visible. For example, the master/slave metaphor is used in computer science, engineering, photography, and entomology. A coalition of professional societies, as well as journal editors and textbook publishers, can induce substantive change.
- STEM communication in public spaces has a role to play as well. Recent pieces in the media (e.g., use of pudendum, change to Spongy Moth) have cast a spotlight on the problem and generated conversation across disciplines.



- Collaboration across disciplines is essential! Scientists and engineers generally are not trained to study language and power structures. Questioning and then eliminating problematic terms will require collaboration between the primary users of the language (e.g., some STEM fields) and those who study it (e.g., humanities scholars and social scientists).
- Funding agencies could highlight this issue and require multidisciplinary teams to tackle it. The NSF Broader Impacts language might include specific reference to non-inclusive language. Research

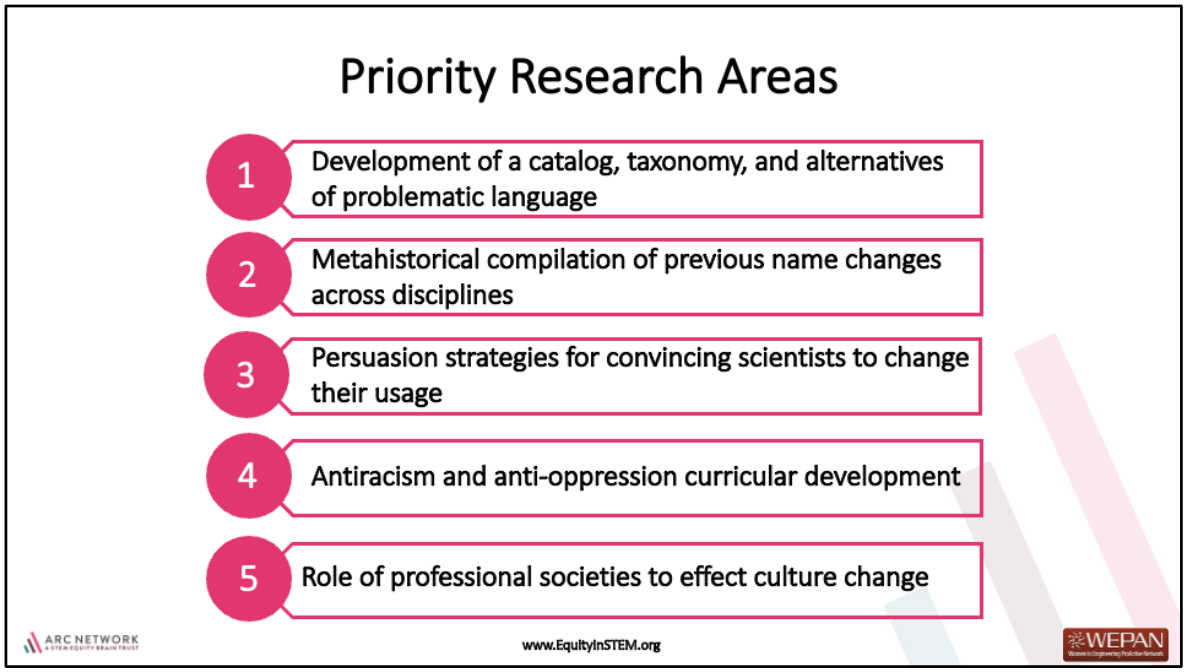
Experiences for Unsdergraduates (REU) programs also might be a good place to start since they require ethics training.

- Compiling dictionaries of scientific metaphor and histories of jargon change (e.g., Mongoloid to Down syndrome; Rodriguez-Hernandez & Montoya, 2011) would be very helpful.
- The arts can certainly contribute to this conversation as well. For example, the field of graphic medicine uses comic book techniques to explore issues in health care (Graphic Medicine, 2022).



- Some will not need to be persuaded and others will be unpersuadable: focus on the middle ground. Even these individuals, though, will need to see data on the issue.
- Focus on their values; if inclusivity is a value, then language needs to be as much a part of the discussion as unconscious bias has become.
- Scientists pay close attention to action from professional societies, journals, and funding agencies. Educators tend to be more receptive to these messages about inclusion, so perhaps start with the education sections of societies and funders.

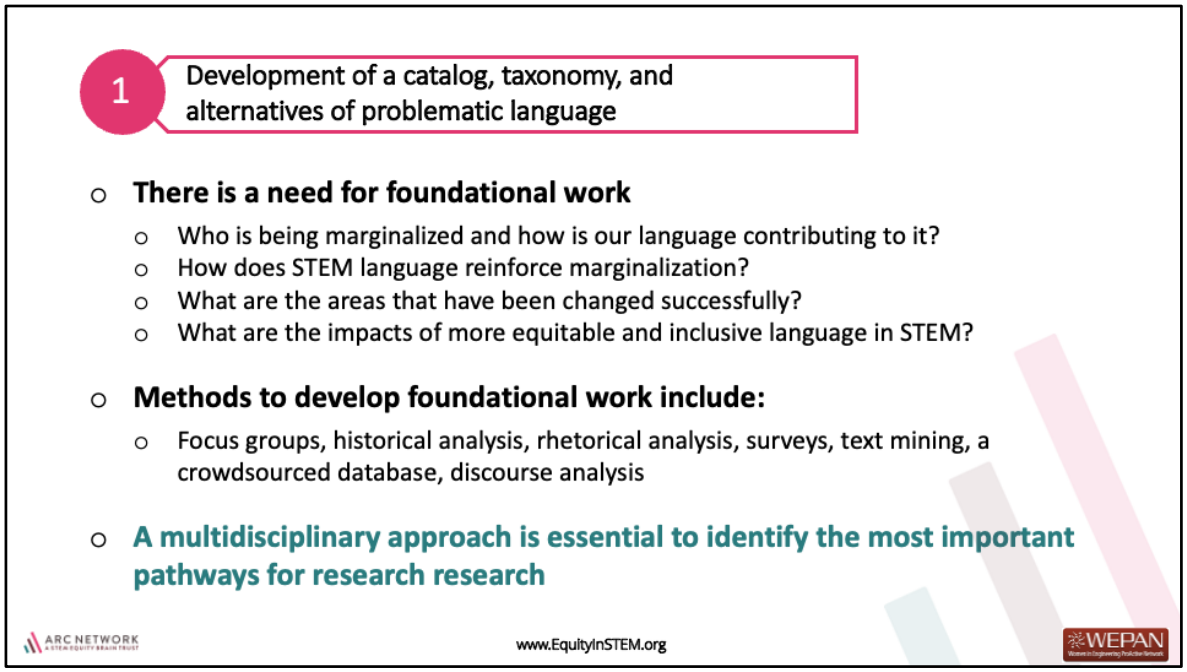
- Healthcare practitioners focus on outcomes, so tying language use to health outcomes is essential.
- In some cases, institutional review boards (IRBs) can play a role; because they include non-specialists and members of the public, problematic language may be flagged that otherwise is overlooked.
- Textbooks can alter pedagogy, especially when large prestigious institutions adopt them.
- Both top-down and bottom-up approaches are needed, with support given to those individuals advocating for change.
- Stories are always persuasive, so collecting stories about how language is perceived by others is important.



After discussion, participants showed a strong interest in further developing five priority research areas:

1. Development of a catalog, taxonomy, and alternatives of problematic language
2. Metahistorical compilation of previous name changes across disciplines
3. Persuasion strategies for convincing scientists to change their usage
4. Antiracism and anti-oppression curricular development

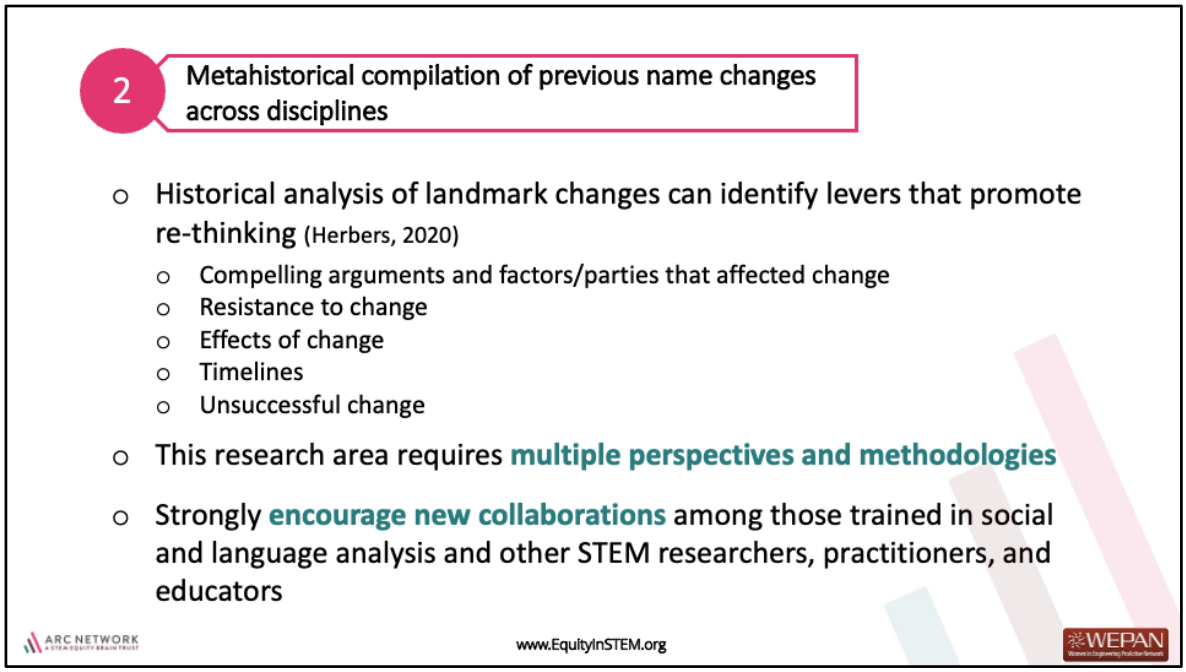
5. Role of professional societies to effect culture change



Given that ours was the first workshop on the topic of problematic terms, there is a need for foundational work:

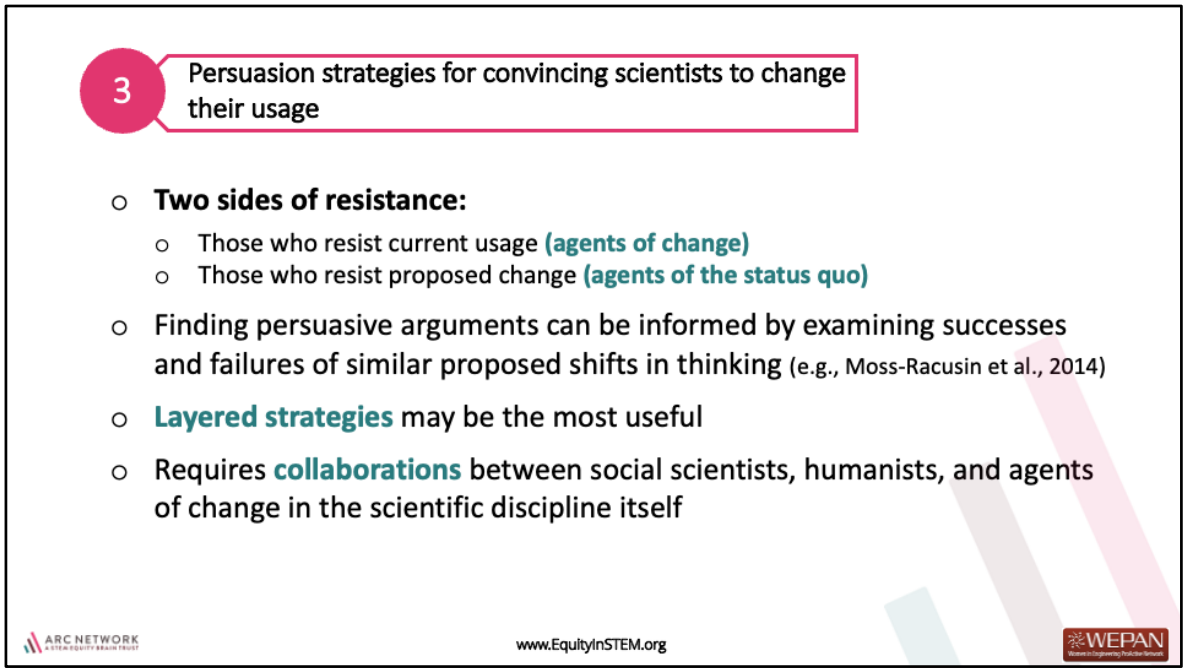
- Who is being marginalized and how is our language contributing to it?
- How does STEM language reinforce marginalization?
- How variable are perceptions of these terms and their effects?
- What are the priorities for redressing potential harm from language use?
- What are the areas that have been changed successfully?

- What are the social constructs and social implications of word choice?
- What alternatives might promote inclusivity?
- What are the impacts of more equitable and inclusive language in STEM?



Important examples of scientists abandoning harmful metaphors exist (e.g., use of "rape" to describe forced copulations in animals; Zuk, 1993), and we now need to collect and analyze such examples (Appendix II). Historical analysis of landmark changes can identify the compelling arguments and factors/parties that affected change, as well as resistance to change, effects of the change, and timelines. Just as important, we must analyze those calls for shifts in terminology that were *not* broadly successful (Herbers, 2020).

This research area also requires multiple perspectives to explore interconnectedness of colonialism, sexism, racism, xenophobia, homophobia, transphobia, etc. so once again collaboration is a key suggestion.



We must also ask the question ***what causes scientists to question and possibly change accepted usage***? What are the points of resistance to change and how can we counter them? In what ways do these connect to values held by scientists (about truth, enhancing learning, contributing to the profession, etc.)?

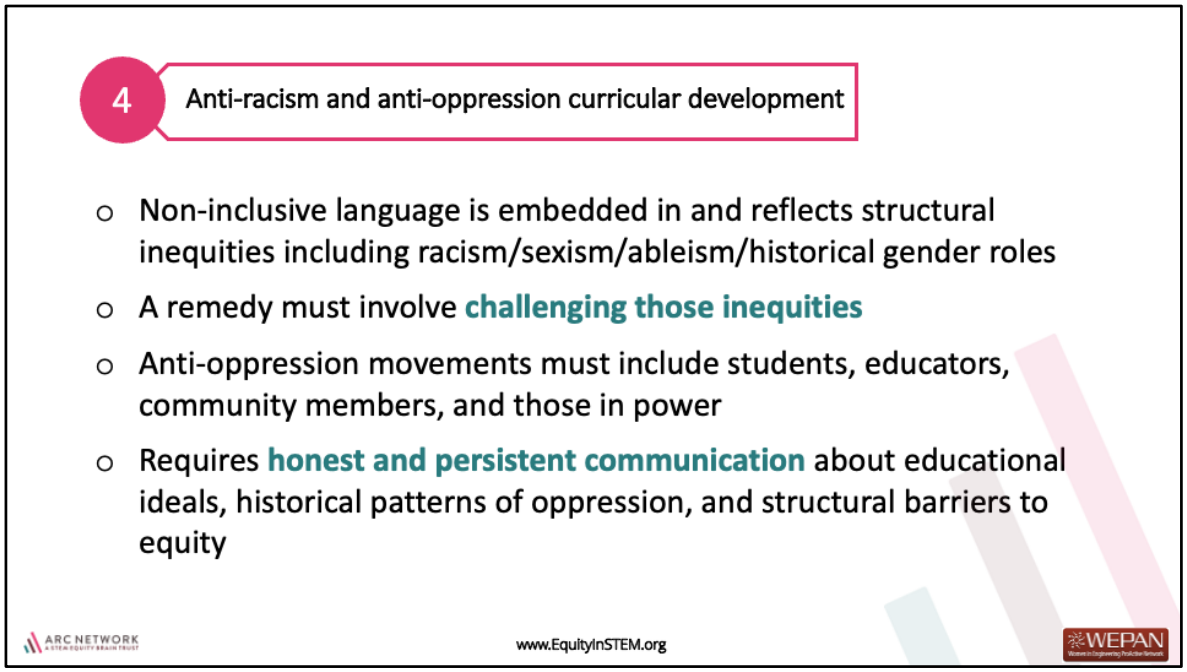
The concept of resistance has two sides. There are those who resist current usage (*agents of* change) and those who resist proposed change (*agents of the status quo*). We must understand both groups: what motivates those who propose change, and what arguments are most likely to persuade others that such change is needed? Further, we must develop strategies to support both.

If our goal to change language use is to be successful, we must understand how scientists think about social issues within their disciplines.

Layered strategies are likely to be useful. For example, senior or more established scientists may not be receptive to calls for change to entrenched terminology, but their students may be. Those working in research-intensive institutions, who generate much of the literature that uses problematic jargon, are likely both to be early adopters of change as well as resistors. Those working in teaching-intensive

institutions have less power to change accepted terminology across a discipline but may be instrumental in identifying and documenting harm done by such terms. Journal editors and professional societies can play major roles by developing policies for acceptable terminology (*leading indicators*), and usage can be tracked in textbooks (*lagging indicators*).

Pursuing these agendas will require collaborations between social scientists, humanists, and agents of change in the scientific discipline itself. It is likely that different branches of STEM will require different approaches as well.

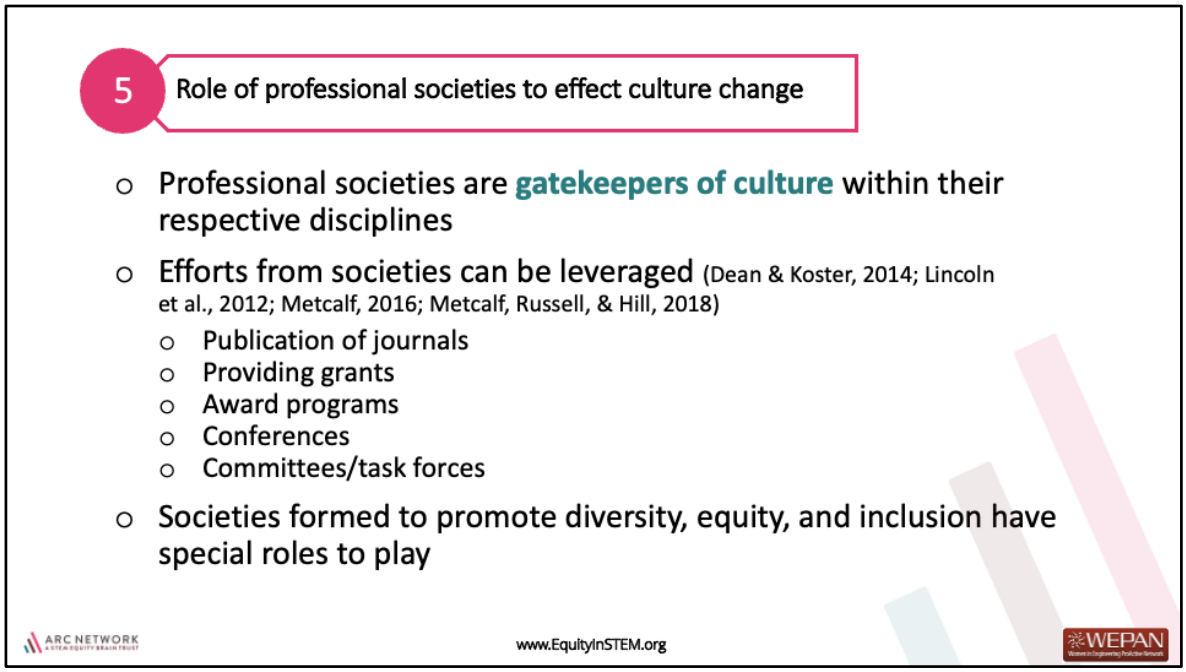


This topic acknowledges that non-inclusive language is not a stand-alone problem but is embedded in and reflects structural inequities including racism/sexism/ableism/historical gender roles and the like. Thus, a holistic remedy must involve challenging those structural inequities by dissecting power structures, and associated allocation of privilege.

Anti-oppression movements must include students, educators, community members, and those in power. Numerous disciplines must weigh in, from arts and humanities through to medicine and engineering.

Furthermore, acknowledgment and analysis of structural oppression must pervade every discipline in the classroom and workplace.

The issue of community respect for education (especially public education) is complex and retaining/ regaining public trust will require honest and persistent communication about educational ideals, historical patterns of oppression, and structural barriers to equity.



Professional societies are gatekeepers of culture within their respective disciplines, and scientific/engineering societies in particular can influence thinking among their members concerning inclusive practices. Furthermore, the broad membership of societies (researchers, educators, policymakers, including those in academia, government, NGOs, and the private sector) gives them leverage for achieving structural change.

Societies formed to promote diversity, equity, and inclusion have special roles to play. Those that serve historically marginalized groups share the goal of inclusivity, and a coalition of these societies that focus on language use could be especially powerful. In particular, they can work with and highlight grass-roots efforts among their members to suggest language changes that promote inclusivity.

Next Steps

ERW Reports

We encourage researchers to pursue the topics and explore the questions described within each report and discussed here today

Visit www.EquityInSTEM.org to read the available concept papers

Contribute to the papers by visiting www.surveymonkey.com/r/ERW-paper-feedback

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WEPAN

While the workshops have ended, we hope the conversations around these topics have not. We have not currently provided active forums for workshops participants, but rather have left it to individual initiative to organize future collaborations. However, we hope to spark additional interest and collaborations through webinars on the topics.

I also encourage you to explore the emerging research workshop reports that go into further detail on what I've discussed in my presentation and include other avenues of research that may be of interest to you.

Thank you for attending this presentation!