Asking Different Questions in STEM Research: Feminist STS Approaches to STEM Pedagogy

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Abstract

Using the example of a new pilot curriculum developed at the University of California, Davis Feminist Research Institute, we demonstrate the potential of feminist science & technology studies (FSTS) frameworks to connect the challenges of demographic diversity at the level of the institution with the challenge of epistemological diversity at the level of how we approach research in STEM fields. Dominant ideals of scientific objectivity imply that researchers must leave their personal identities and experiences behind to pursue research. However, most scientists know this is not the lived reality of scientific practice. In reality, researchers cannot help but bring their biases into the lab, and the history of science bears this out (Daston & Galison, 2007; Subramaniam, 2014). A FSTS perspective suggests that institutional change requires structures that promote and reward research that includes the experiences of people historically under-represented in STEM fields, particularly connecting issues of under-representation to the production of new scientific discoveries. We argue that the "Asking Different Questions" pilot curriculum illustrates the potential of STEM research training curriculum to utilize theory and analytical tools from FSTS and Critical Race and Ethnic Studies to help people situated in STEM fields to understand the relationship between efforts to bring more diversity into science and the need for new approaches to scientific research.

Keywords: social justice, STEM education, ethnic studies, gender studies, science and technology studies, feminist studies, epistemological diversity

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Dominant ideals of scientific objectivity imply that researchers must leave their personal identities and experiences at the lab door. And yet, as most scientists know from experience, this is not the lived reality of scientific practice. In reality, researchers cannot help but bring their individual bias into the lab, as well as those of their research discipline and community, and evidence from the history of science bears this out (Daston & Galison, 2007; Subramaniam, 2014). We define bias at the individual level as an inclination towards or against a given idea, object, group or individual deriving from variables in that individual's background and experience. We also refer to bias at the level of research communities across scales. The shared norms of scientific research culture derive from cultural norms of white European, middle-class, able-bodied, masculine, heterosexual communities. The inclusion of both diverse representation and diverse knowledges has been shown to help control for biases that are part of the (Anglo-European, middle-class, able-bodied, masculine, heterosexual) norm in scientific research culture (Cipolla et al., 2017; Foster, 2017; Hamraie, 2017). For this reason, we need to change our structures and practices of knowledge production to include the experiences of people historically under-represented in STEM fields, particularly by connecting issues of under-representation to the production of new scientific discoveries. In practice, this means that research training design in STEM fields should address the need to change our structures and practices of knowledge production to include the experiences of people historically under-represented in STEM fields, particularly by connecting issues of under-representation to the production of new scientific discoveries. This paper argues for the potential of feminist science & technology studies (FSTS) frameworks to demonstrate the connection between demographic

diversity and epistemological diversity (different ways of knowing), and the potential impact of understanding that connection for STEM fields. This paper first describes the perceived need and value for a research training program that demonstrates the connection between demographic diversity and epistemological diversity, and the potential to teach research design for epistemological diversity in STEM fields. We then detail the design and early impact data of "Asking Different Questions," a curricular research training program for STEM graduate students that applies feminist science & technology studies (FSTS) frameworks. Finally, we discuss the early success and also the early findings on the limitations of this approach.

The field of FSTS has a rich history from which to understand the relationship between efforts to bring more diversity into science and the need for new approaches to scientific research (Beddoes & Borrego, 2011; Prescod-Weinstein, 2020). Based on feminist critiques of epistemology and FSTS's standpoint-based critiques of the concept of objectivity in science, we designed a research training curriculum anchored in the analysis of the relationship between science and culture. Standpoint theories begin from the assumption that who produces knowledge matters for what kind of knowledge is possible. Standpoint epistemologies flip on its head the idea that observation from a supposedly neutral or more removed position is best by instead arguing that those observing from marginalized viewpoints which are often closer to the situation at hand will produce more accurate knowledge (Collins, 2002; Harding, 2004; Thomson, 2017).

Even given the success of programs like NSF's ADVANCE in recruiting a more diverse professoriate in university STEM fields, shifting the culture of STEM research towards retention of women and under-represented minorities and realizing the potential of this diversity remains

challenging (Bisson et al., 2022).[1] In response, the authors developed a research training program at UC Davis whose early success argues for the positive role that feminist science and technology studies (FSTS) approaches can play in shifting the culture of STEM research to value and reward diversity of epistemology as well as representational diversity.

Funded by a National Science Foundation "Innovations in Graduate Education" award titled, "IGE: A Pathway to Inclusion for STEM Researchers," the rationale behind developing a training for STEM graduate students in FSTS and critical race and ethnic studies (CRES) approaches was to maximize the potential of a more diverse community of researchers to produce contextualized, and therefore stronger scientific results once they have been recruited and hired. Not only is unequal representation unjust, but it also leaves the scientific community more prone to replicate past injustices (Benjamin, 2013, 2019; Noble, 2018; Roberts, 2012). Valuing diverse representation in the lab and classroom allows researchers to bring in expertise from both their scientific training as well as from their lived experience. This inclusion of both diverse representation and diverse knowledges has been shown to help control for biases that are part of the (white European, middle-class, able-bodied, masculine, heterosexual) norm in scientific research culture (Cipolla et al., 2017; Foster, 2017; Hamraie, 2017). Thus, we argue that there is an imperative to explore new avenues for moving from the diversification of who is

[1] For example, UC Davis was awarded an NSF Advance Award to increase recruitment of diverse faculty from Division of Human Resource Development titled, UC Davis Advance: Institutional Transformation to Build and Sustain a Diverse Community of STEM Scholars," Award # 1209235. The potential of its 2012 NSF ADVANCE grant was maximized through a strong institutional commitment to, and focus on, recruiting Latina faculty. This focus reflects the demographics of California as well as those of UC Davis's undergraduate population. This project was successful in recruiting faculty and diversifying the number of women in the UC Davis professoriate. However, at UC Davis and other institutions that have benefitted from programs like NSF ADVANCE, challenges persist in retaining those faculty, and questions remain about how to spread the benefits of this program to meet broader challenges in higher education beyond representation in hiring. Even with improvement in faculty recruitment and hires, unequal representation persists at more senior research and leadership levels.

in the lab to diversity of the research questions, expertise, and approaches that are valued and privileged in research practice.

This paper discusses a case study of participant data from the "Asking Different Questions" pilot curriculum project at the UC Davis Feminist Research Institute. This curriculum was designed to expose STEM researchers who are already invested in equity and inclusion in the academy to FSTS approaches to STEM research. These participants were recruited for the pilot program through their interest in diversity and equity in institutional representation, which often supported their willingness to explore the possibility for epistemological diversity as a potential way to support the former, even if they had no prior exposure to the concept of epistemological diversity in science. Using feminist pedagogical techniques based in participatory learning and the incorporation of individual personal experience in the classroom, the curriculum asks participants to rethink traditional assumptions in their fields and approaches to research, to investigate new kinds of research questions, to experiment with shifting their frames of data analysis, and to rethink applications of their research findings. We see this type of epistemological project as part of a necessary effort for improving retention of diverse faculty, and potentially improving the accuracy of scientific results.

Background

The Asking Different Questions (ADQ) research training program at UC Davis was designed to introduce STEM researchers to the value of incorporating epistemological diversity into research design. To this end, the program offered training in how to change the types of research questions asked and the assumption behind them, reframing methods, models and analysis by offering case studies of research that successfully incorporates the diversity of background and experience among researchers. The curriculum includes materials that share data

demonstrating potential impact of valuing epistemological diversity in research for retaining those researchers historically under-represented in STEM (Subramaniam, 2009). This is because, as FSTS scholarship details, the systems of exclusion that created homogeneity in science also dictated the knowledge structures and norms of science. The ADQ curriculum answers this limitation by decentering a privileged individual observer and author of scientific knowledge. Instead, the program highlights how a single researcher can only have a "partial perspective" unique to their standpoint (Haraway, 1988). In practice, this means that research observations must be understood as offering "situated knowledge" rather than a neutral all-encompassing "god's eye" view (Ibid). The overall curricular goal is to show that as a result, the culture of science, as well as the accuracy of results, can be improved by attending to a plurality of knowledges. This plurality offers a greater wealth from which to understand the world and make decisions. These FSTS frameworks reveal how the "best" answer depends on the context of a given research question and provides tools for how to critically make more informed choices in research design and analysis. These tools offer a path for STEM researchers to create more honest and whole knowledge, rather than relying on any singular perspective imagined as objective and complete on its own.

Approach

Research in STEM pedagogy and feminist STS indicates that understanding the cultural context for scientific research not only creates more just science—it also builds knowledge that is more objective and accurate (Longino, 1990; Reardon, 2013; Reardon et al., 2015). FSTS argues that removing all aspects of power and bias from scientific research is an impossible ideal given the intense relationships between science, politics, and culture. By focusing on this unrealistic ideal, dominant viewpoints appear neutral and go unquestioned while marginalized

positions are more likely to be pointed out and eradicated. Accepting this reality, FSTS scholars argue that instead of trying to remove all biases, we should instead see knowledge as always "situated" in culture, as always historically contextual (Haraway, 1988; Tallbear, 2003). All research projects begin with a set of underlying ethical assumptions, and attending to the situation of the research and historical context helps surface these. These assumptions contain in and of themselves an ethic (Barad, 2007; Haraway, 1988). They frame what questions it is possible to ask, and who bears the burden and benefit of research. These scientists and theorists argue that once we leave behind the ideal of absolute neutrality (Harding, 2008), we will be able to produce more responsible and accountable science.

The standpoint informing the development of our curriculum brings together feminist and critical race and ethnic studies (CRES) critiques of science. We use a definition of feminism summarized by feminist STEM education scholars Crawley, Lewis, and Mayberry (2008), "feminism is … a way of orienting to academic work that is attuned to power relations, both within the academy and within knowledge construction itself." Therefore, we emphasize in the curriculum that feminist inquiry is not simply about "women" but is more appropriately described as research into "how power operates" in the situation at hand. To understand how power is operating, we must understand power within a historical and global context at the same time as being attentive to the specificity of the immediate context of the situation under analysis. To this end, we utilize case studies in indigenous studies and ethnic studies that demonstrate precedents for the roles of community-based values and knowledge as one way to address historical injustice. We also introduce students to the models of community-based and community-led research as additional way to engage a diversity of knowledges. The resulting application of this framework can (a) reveal deep bias in scientific research and (b) suggest

methods and frameworks that produce more accountable, accurate and responsible scientific research. Feminist and CRES approaches to STEM research are shown to improve objectivity by recognizing all observation as coming from a partial perspective, and to strengthen objectivity for the purposes of greater equity, by attending to the role of power and context (Barad, 2007; Harding, 2004). A scientific community with diverse life experiences and values is more likely to notice bias or neglected social issues in research, thus improving scientific objectivity and the responsiveness of scientific research to the plight of those marginalized in today's society (Intemann, 2009). These conclusions challenge the idea of absolute neutrality in the sciences by acknowledging that the knower/observer impacts the scientific "discoveries" that are possible.

Our approach to designing this curriculum is informed both by feminist standpoint epistemology and its critiques. Sandra Harding explains that FSTS is well-positioned to acknowledge the types of expertise and understandings of power that individuals and communities have when they are oppressed by it (1992). This is a tenet of standpoint epistemology we include. However, FSTS approaches do not advocate for epistemological relativism, in which "(often conflicting) standards that different groups use [are considered] equally valid, equally good" (Harding, 1992, p. 576). The Harawayan partial perspective approach used in our curriculum guides students towards what Harding terms "strong objectivity." Strong objectivity "aims to reveal social assumptions that

> (a) enter research in the identification and conceptualization of scientific problems and the formation of hypotheses about them (the "context of discovery")
>
> (b) tend to be shared by observers designated as legitimate ones, and thus are significantly collective, not individual, values and interests, and

> (c) tend to structure the institutions and conceptual schemes of disciplines. These systematic procedures would also be capable of
>
> (d) distinguishing between those values and interests that block the production of less partial and distorted accounts of nature and social relations ("less false" ones) and those- such as fairness, honesty, detachment, and, we should add, advancing democracy- that provide resources for it." (1993, p. 580)."

Built around the foundational feminist critiques of science forwarded by Harding and Haraway in the early 1990s, and the incorporation of community-engaged research approaches developed through CRES and Indigenous Studies (see for example Tallbear, 2013; Benjamin, 2013; Casumbal-Salazar, 2017; Liboiron 2019) our approach complements "critical contextual empiricism,"(CCE) as detailed by Fuselier, Jackson and Stoiko (2015). Building on the work of Helen Longino, the authors cite the origin of CCE in Longino's argument that "knowledge is inherently social because it is produced by communities, not individuals" (242). Focused on "knowledge producing communities," authors highlight Longino's four qualifications for a sociality of process that ensures objectivity: 1) when the process includes public presentation and critique of findings, 2) response to that criticism, 3) adherence to public standards of community belonging, and 4) grants intellectual authority based on exposing knowledge to diverse criticisms, knowledge claims will account for criticism from multiple points of view while not leading to relativism. The authors explain that their articulation of Longino's treatment of CCE, like our treatment of a partial perspectives approach, also derives from situated knowledge (Haraway, 1989) and strong objectivity (Harding, 1991).

Methods: Asking Different Questions Curriculum Development

In 2017, we proposed a curricular intervention that would create a graduate curriculum training that allows STEM graduate students to apply insights from FSTS to their own research fields. The curriculum is meant to address the challenge of bringing together the drive to increase diverse representation in STEM while promoting a partial perspectives/strong objectivity approach to diversifying epistemological approaches in STEM. We call this program Asking Different Questions (ADQ). Asking Different Questions is named in reference to Deboleena Roy's essay, "Asking Different Questions: Feminist Practices for the Natural Sciences" (2008), which in turn is a nod to a Canadian film by the same title (Basen & Buffie, 1996). In the essay, Roy describes how applying lessons from FSTS to scientific research can impact research agenda choice. ADQ seeks to apply a wide range of FSTS scholarship to exploring the extent to which changing research questions and agendas to account for the observers' sociocultural contexts will contribute to greater inclusion and sense of belonging for those historically under-represented. This program provides a framework for students to create more equitable research agendas and foster deeper collaborations with social sciences, humanities, and arts. Tools include recognizing historical bias, placing research in a broader context, and working with complex research questions. For example, ADQ grapples with the historical specificities of STEM field formation that (sometimes explicitly) excluded people who remain under-represented based on race, gender, ability, and other social categories. The curriculum considers how these histories persist through norms and accepted knowledge production practices. This goes beyond an examination of bias and addresses how the premise of what is considered a valid research question can act as a seemingly innocuous site of exclusion.

ADQ utilizes student-centered active learning to discuss topics such as the politics of doing science, bias in research, and issues of identity in concise, one-hour sessions. By connecting insights from FSTS with STEM graduate training, ADQ impacts not only the kinds of research undertaken, but also what it means for science to be ethical. Central learning outcomes for the program are as follows: identify, differentiate, and debate competing theories on knowledge and its production; describe the relationship between culture & science; analyze how power dynamics, histories, and cultures shape traditional sciences; compare & contrast models of scientific knowledge production that challenge traditional competitive and hierarchically-driven science methodologies; and apply feminist approaches to scientific research.

The curriculum provides participants with tools from FSTS that have proven results in posing questions that can lead to more accurate and more ethical scientific research. These include the following: What is the historical context and how does it continue to impact research today? What are underlying assumptions and how might they be informed by past systems of inequity? Who is impacted by research questions? Are the benefits and costs equally distributed, particularly considering historical precedent? How do lab cultures influence scientific results? How can the scientific community better address public controversies about research by understanding the histories that have led to mistrust?

In order to build a curriculum that spoke to the needs of STEM scholars at UC Davis, the authors created a working group that met for 10 weeks in Spring 2019. All three authors are trained in science and technology studies and developed the approach and feminist pedagogical practices behind the curriculum. One author (Giordano) additionally has STEM Ph.D. training, and another (Vora) has additional Ph.D. training in CRES. All three authors have experience

teaching graduate students in FSTS, but created the working group to gain insight into how best to present our FSTS approach to a diverse graduate STEM audience. To recruit the working group, McCullough and Vora drew on the community of scholars brought together through the UC Davis Feminist Research Institute's (FRI) scholarly community, as Associate Director and Director respectively. This community had been previously built through FRI's fellowship programming and events that brought together humanistic and scientific interests. Each week, the ADQ working group explored a different challenge present in STEM and feminist approaches to addressing this challenge. Broadly, the group discussed challenges such as how to recognize and address issues of historical bias and cultural complexity, place research in a broader context, and better frame complex research questions, particularly those presented by communities traditionally under-served by science. Participation is majority-minority in that women and URMs are highly represented. A wide swath of disciplines participated from nearly all colleges.

This community of scholars helped to inform the creation of the curriculum and formed the core of outreach efforts for program implementation. The explicit rationale for the curriculum is built on the assumption that the attrition of women, Black, Latinx, and Indigenous scholars from STEM fields is not only due to explicit sexism and racism but also because of a disconnect between the kinds of questions that are deemed appropriate to these fields and the interests of students from marginalized communities. Therefore we need to rethink how research questions are determined if we are serious about creating more diverse STEM fields. Having more explicit conversations about the politics of scientific practice and research is an impactful site from which to integrate the experiences and values of those historically excluded from the university. Feminist science studies and ethnic studies have extensive tools to guide this conversation.

By pairing the expertise from this working group with our knowledge of FSTS, we created four learning objectives:

1. Identify, differentiate and debate competing theories on knowledge and its production (epistemology and philosophy of science)
2. Describe the relationship between culture(s) and science (including race, gender, sexuality, coloniality, capitalism, ability)
3. Gain tools for identifying and understanding effects of history of research field on how knowledge is organized and valued
4. Gain experience applying feminist research approaches to (a) frame individual research project, (b) communicate social justice imperatives in research, and (c) communicating feminist approaches in their field.

With these learning outcomes in mind, authors used their training in FSTS and CRES to develop a set of topical modules to test with the workshop. We organized the curriculum around the eight topics that were projected to be received strongly across workshop participants' areas of expertise:

Table 1

Module topics and descriptions

Module Topic	Description
The Politics of Doing Science	How does culture influence science and what changes are necessary to bring about more just scientific research? This session uses contemporary controversies to examine how histories of domination continue to impact ongoing scientific practice. Participants will learn how to compare competing theories of knowledge, describe the relationship between science and culture in their field, analyze how power shapes scientific debate, and engage in a reasonable discussion about the future of science. Case studies may include the proposed building of the Thirty Meter Telescope at Mauna Kea the building of pipelines and border walls, research at burial sites, sites of environmental injustice, and superfund sites.

Identity and Belonging in Science	How does our identity and position in the world affect our work as researchers? To what extent do we "fit in" to the culture of our lab and field? How is this fit influenced by histories of the field and the shaping of disciplines? How does this affect the research questions a field prioritizes? Participants will learn how historically salient identities such as race, gender, sexuality, class, nationality, and disability affect cultural norms of science. They will also explore how starting from different social assumptions can produce knowledge aimed at increasing social justice.
Identifying Bias in Scientific Research and Training	How have the histories of exclusion in science become embedded into the field, including the metaphors, languages, and scientific practices? How does a field's choice of language and metaphor affect the scientific process? The language and metaphors used in a field, or even the instruments developed, can carry with it unintended biases and assumptions. These choices can impact public uptake of findings, influence applications of research, and foreclose potentially rich lines of inquiry. This session examines the language and metaphorical practices used to identify key signifiers that may be limiting the possibilities of scientific inquiry, and how shifts to contrasting language and concepts lead to new scientific discoveries and produced more equity.
Making More Accurate Knowledge	How can more nuanced models of objectivity allow us to represent more accurately our research findings? Scientific findings are often messier and situated in specific historical, institutional, and cultural conditions that go unacknowledged in published findings. The session explores how models of objectivity have changed over time within the scientific community, and potential new, more accurate models that account for how science and culture interact.
Studying Race, Sex, and Gender	How can we study race, sex, and gender in ways that are more precise to produce better research results? Race, gender, and even sex are sociocultural constructs. Yet they have real impacts on our daily lives and well-being. How can researchers best take these important identity markers into account without succumbing to a false biological determinism? This session identifies common pitfalls that undermine research findings, and more productive pathways.
Hierarchy and Accountability in Science	How do hierarchies of science and systems of power influence science? How do the ways we are beholden to funding and administrative structures impact the knowledge we produce? Participants will discuss how hierarchies influence the types of research questions that we can ask, the type of work we can do, how to conduct research, and the methods we use. How can more acute attention to the complexity of hierarchies help us to do better, more intentional research? This session also explores alternatives systems of accountability that shift research commitments to be in solidarity with those most vulnerable.

Addressing Legacies of Colonialism in Science	How do the histories of colonialism continue to inflect scientific research? Legacies of colonialism impact what is considered a valid research question or approach today. This session examines how histories of colonialism and empire influenced the emergence of disengagement as a value of scientific practice. Learn how traditional notions of objectivity support an ideal of detachment from the object of study, a divide between observer and observed. Consider instead an approach based in relationality that more accurately reflects the lived reality. The case study reading centers approaches in indigenous science.
Moving from Asking Different Questions to Action-Oriented Change	How do we apply the many concepts presented in this training series to produce tangible change? What is the process of making a research plan based on some of these concepts that is right for you? This final episode of the series prepares a research community to enact action-oriented change by walking through a practical, step-by-step, iterative process for envisioning, planning, and implementing tangible change.

Curriculum Delivery Year One

Most participants encounter the curriculum as part of a quarter-long series of eight modules. In one-to-1.5-hour long sessions, they learn foundational concepts from FSTS, see those concepts applied in a STEM context, and then engage in small group discussions. Some graduate students enrolled in a longer, seminar version. The seminar expands upon the module format through the inclusion of supplementary readings and application activities that culminate with the creation of a final project. Designed as a 10-week seminar, the progressive weekly units guide participants in (a) conceptualizing their research problem through feminist commitments to justice, (b) drafting a research design/presentation module incorporating feminist methods and approaches and (c) building support for potential challenges in future research practice following the course. Students learn to design research projects that achieve results that both make significant contributions to their research field while also being committed to social justice outcomes. At the end of the seminar, participants workshop modules to teach back course material by designing a module for their peers.

For example, two first-year Ph.D. students in environmental science designed a one-hour module to introduce future first-year peers to the ADQ FSTS partial perspectives approach to research. Their goal was to increase awareness and reflexivity about the impact of environmental science with the goal of conducting ecology research that reduces harm and is more ethical, inclusive, and transformative. They targeted first-year graduate students as researchers having autonomy and flexibility to incorporate new methods and frameworks. Using case studies in microbiology (Wayne, 2000) and indigenous science (Kimmerer, 2015) borrowed from the ADQ curriculum, they demonstrated the potential to produce better science through a partial perspectives approach. Importantly, and as will be discussed in the next section, their module mirrors the authors' own research finding that a general curriculum can most productively aim to start a conversation and identify resources for specialists to pursue field-specific research topics.

Table 2

Sample Modular Case Study and reading list

Module Topic	Sample Case Study	Sample reading list
The Politics of Doing Science Challenges addressed: ●Understanding how culture and politics influence science ●Addressing public controversies about scientific research (and infrastructures) Key terms: Indigeneous Science Settler Colonialism	Mauna Kea and the Thirty Meter Telescope (TMT)	Casumbal-Salazar, Iokepa. 2017. "A Fictive Kinship: Making 'Modernity,' 'Ancient Hawaiians,' and the Telescopes on Mauna Kea." Native American Indian Studies 4 (2): 1–30. Herman, Doug. 2015. "The Heart of the Hawaiian Peoples' Arguments Against the Telescope on Mauna Kea." Smithsonian. Accessed July 18, 2019.

This curriculum and its uses of feminist pedagogy adhere to best practices in student-engaged learning. Pedagogical approaches that center student learning, address power dynamics, and make space for students' unique expertise as developed through their life experiences can be particularly valuable for those historically under-represented in the academy. Being able to bring one's community history and lived experiences of marginalization into research design improves outcomes and contributes to the retention of women and under-represented minorities in STEM (Cech et al., 2017; Diekman et al., 2015; Smith et al., 2014). Thus, changing how STEM is taught is a common theme in FSTS scholarship. For example, in the *Feminist Science Studies: A New Generation* reader, a full third of the book is dedicated to pedagogy and educational interventions (Subramaniam & Weasel, 2001). Trends identified include creating more ethical student-teacher relationships, engaging in active student learning, doing community engagement beyond the classroom, challenging pure objectivity, and attending to social justice. Because of this, we deliver the curriculum in a participatory delivery module that allows participants to (a) connect their diverse background experience to their lives as researchers and (b) offer peer education to each other, enhancing their understanding of why diversity in STEM improves scientific outcomes. We do this by using case studies as a starting point to teach key concepts, and then use guided participatory activities including in-session readings that invite students to apply these concepts to their own research and training, and educate their peers through sharing their observations.[2] In the graduate seminar, we follow this with discussion of pre-assigned readings and provide a list of further recommended readings.

[2] This approach is informed by two successful previous National Science Foundation projects: Women and Scientific Literacy: Building Two-Way Streets (BTWS) and the Science and Justice Training Program (SJTP). Both programs rely heavily on insights from feminist science and technology studies as a field of research capable of enhancing critical science literacy and introducing a rigorous encounter with social and cultural contexts into the scientific process. Both make strides to break down the traditional barriers that exist between the "hard" sciences and the social sciences and humanities by facilitating interdisciplinary approaches to the acquisition and critique of

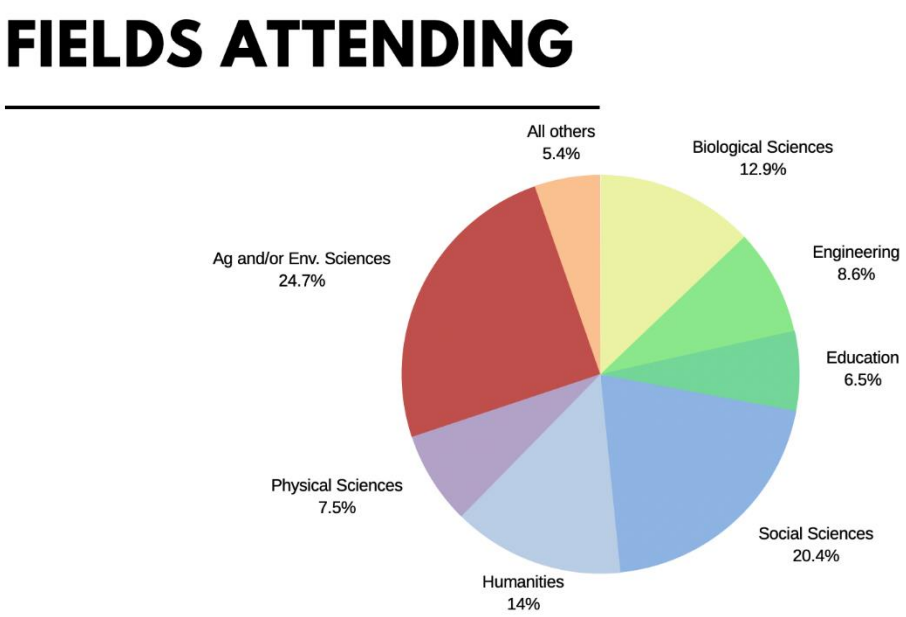
Preliminary Results

The first year of the ADQ program invited Ph.D. students from across STEM, social sciences and humanities to attend a series of eight one-hour modules, either independently or as a full series. It drew participants from across the disciplines and all colleges at UC Davis (biological sciences, engineering, letters & science, agricultural & environmental engineering). We surveyed participants for basic demographic information, and for qualitative feedback on learning outcomes and volunteered comments on impact. In year one, we found that 55% of participants self-identified as under-represented in their field, and expressed high satisfaction with the program. While the program targets graduate students, faculty and professional researchers have also participated. 100% of those who attend early sessions in the series plan on attending again. 89% would recommend them to a colleague, and 89% plan on taking action based on what they learn in the trainings.

knowledge for the purposes of addressing issues of real-world significance. See Musil 2001, 12; (Reardon et al., 2015; Reardon, 2013)

Figure 1

Fall 2020 ADQ participant representation by field



Participants reported applying ADQ training to their teaching, research, and lab work. One faculty member spoke of plans to incorporate indigenous sciences into their class on microbiology. A health science researcher planned to seek out more diverse data sets to study health disparities. A principal investigator decided to change their lab culture to be less hierarchical and more open to new ideas. These are all tangible, specific changes that contribute to greater equity in STEM and potential retention of those historically under-represented. Some graduate students join the program because they do not feel that there is a place for them in STEM and hope that the training will help them find a new direction. They leave with new ideas for how they can change their research agenda and challenge systems that exclude them. They experience a sense of community that contributes to retention. For many universities, retention can be a greater problem than recruitment of those historically under-represented. Campus

climate is often identified as a key factor (Griffin et al., 2012), and the culture of STEM is part of that dynamic, which this program directly addresses.

While the FSTS content remains central to the program, ADQ also rests upon the importance of collaborative learning grounded in feminist pedagogies. Feminist pedagogies emphasize how hierarchies of knowledge and traditional notions of expertise can dismiss historically oppressed voices. University-trained skills are often more valued than skills learned through one's life experience, particularly the life experiences of those marginalized because of race, class, gender, ability, or sexuality. Thus, the research training utilizes facilitated discussions of key topics, which allows participants to speak to the subject matter both as trained scientists *and* as experts in their own lived experience as a marginalized person. ADQ also emphasizes the need for collective support and organizing to address systemic challenges in STEM that perpetuate systems of white supremacy, even sometimes in the research that is produced. Participants learn and share practical strategies for how to challenge the "MANEL" (all-male panel) or advocate for precise ways of accounting for sex difference in fields of biological research where that variable is not considered "relevant."

Introducing a socioculturally-informed STEM training that centers the expertise gained from researchers' lived experiences appeals to those underrepresented in STEM fields. Preliminary evidence shows that participants find that the training allows them to discuss issues of bias, power, hierarchy, exclusion, and limitations to research frameworks and methods. These are all areas that concern them greatly, but which they find difficult to discuss in-depth within their field. They appreciate the FSTS research-based foundation from which to ask new research questions that speak to their lived experiences. They have shared comments such as:

> The false notions of objectivity in science and the lack of contextualization and consideration of power dynamics within my field make it difficult for me to trust that we can use the research for positive, transformational change. ADQ trainings give me tools and a lens that can help me in revisioning/imagining a different way to ask questions and collaborate.

This participant elucidates how learning about standpoint epistemologies led them to reimagine their future research agenda. Other participants spoke of:

- continuing the conversations started in ADQ with their lab mates
- changing their ways of thinking
- helping them to feel a greater sense of community

This training is providing connection for those struggling to find it in their disciplines. Lack of community is one of the leading causes of faculty attrition, particularly among faculty of color (Brazil-Cruz et. al., 2022). Thus, creation of community is a top priority in retention efforts. This program is directly contributing to these efforts. This program provides an oasis for researchers who seek to ask research questions less common in their disciplinary field. They can find new mentoring relationships outside of their field with scholars who come from similar backgrounds. This is particularly important for scholars of color and women in some fields who lack mentors of their gender or race. A recent report points out that while two-thirds of California college students are non-white/BIPOC, more than two-thirds of the faculty and leadership are white (Bustillos & Siqueiros, 2018).

Discussion

Based on the evidence of prior scholarship, we contribute the preliminary results of the "Asking Different Questions" curriculum at UC Davis to demonstrate a practical application of

existing evidence that scholars and administrators must connect the challenge of increasing demographic diversity in STEM with the project of fostering epistemic diversity in STEM. It is not enough to include better representation in STEM, we must also make space for insights and experiences from outside the normative culture of STEM, especially when these are in tension with the way things have always been done. Feminist Science and Technology Studies (FSTS) offers powerful tools for how to do this, and the work is grounded in decades of empirical and theoretical research. At its core, this research offers nuanced tools to account for the ongoing role of history, culture, and politics in science. Doing so can produce research that is more impactful, particularly for populations whose concerns have been sidelined by researchers in the past. FSTS offers models for how to better account for bias in scientific research--thus producing more accurate results.

Early results from 1-hour module participants show that they are highly effective at catalyzing conversations about departmental culture, challenges to belonging, limitations to traditional research models, and validating more ethical models of doing research. This program provides researchers with the tools and validation to ask new sorts of research questions that can push them onto successful career trajectories that address real social issues. Intemann (2009) identifies the increased objectivity that a diverse group of scientists provides and argues that this is an often unrecognized broader impact. This program hinges on introducing new ways of forming research questions, collecting and analyzing data, and articulating conclusions.

Our preliminary findings indicate that the limitations of this curriculum are:

1. STEM participants were limited in their abilities to parse the nuances of coloniality, race, and knowledge production.

Suggested change: Instructor can provide structure for close readings of particular sections of reading material. However, participants with pre-knowledge of scholarship on race, coloniality and knowledge production may be underserved by this task.

2. Non-STEM participants need more structure to identify the language biases in their fields, given that module examples come from STEM.

   Suggested change: For audiences that include non-STEM participants, researchers can include examples or case studies from relevant fields.

3. Participants who do not have activism experience or pre-knowledge may find module on feminist critiques of objectivity, and the alternative value of emotional engagement in research, difficult to parse with their scientific training.

   Suggested change*:* Curricular goals can be expanded from conveying the possibility of emotional engagement as a scientific value to include goals of offering more basic exposure to, and teaching of, direct action/collective action to participants who might not be familiar with these forms of change or do not come from an organizing or activist background.

Conclusion

This paper suggests that by integrating FSTS insights into STEM training, we can maximize diversity in the sciences, both demographic and epistemological. FSTS offers the potential to enhance the quality of scientific research and grow its impact for those most underserved in our society. We have defined feminist approaches as strengthening our findings by correcting for individual and disciplinary biases and promoting collaboration and co-creation.

A feminist approach therefore includes a social responsibility and accountability to racial, gender, class, sexuality, national, religious, and ability-based differences.

FSTS scholarship has indicated that specifying the role of history, hierarchy, and power within the cultural context for scientific research not only can create more just science—it also builds knowledge that is more objective and accurate (Barad, 2007; Haraway, 1988; Harding, 2001; Longino, 1990). Without training in feminist analysis and related fields, researchers are often unaware of the implicit cultural biases that they carry into their methods and analyses, sometimes in a way that does harm in the world (Benjamin, 2019; Noble, 2018; O'Neil, 2017). This compromises the integrity and validity of scientific study and can erode public trust in science (Benjamin, 2013; Callison, 2014; Kimura, 2016). Training in the basics of feminist science studies can bring new interdisciplinary perspectives to bear on the formulation of hypotheses, execution of method, and interpretation of data in wide-ranging scientific endeavors—bringing scientific investigation into a new era (Roy, 2008; Schiebinger, 2001). A more diverse research community enacts social justice, not only by broadening access to opportunity, but also by enriching the very nature of science. This includes helping to "generate new research questions; identify limitations with existing models and propose new models; propose a fuller range of alternative hypotheses and interpretation of data; access more accurate and complete data from human subjects; open up new lines of evidence; reveal 'loaded' language in descriptions of phenomena; and more adequately identify and weigh potential risks" (Intemann, 2009).

The Asking Different Questions project is just one intervention among many others possible designed to connect FSTS insights to allied work happening within STEM fields. Based on our preliminary results, we can conclude that graduate student education is a key site for this

intervention, as it is where future researchers are trained and embedded into the norms of academia. Graduate students interact with undergrads as TAs and research mentors. They are the future of the profession, and will shape its contours to come, whether in academia, industry, non-profits, government, or community work. And yet, changes are also needed in K-12 interventions, undergraduate education, faculty training, and institutional policy. Further research and applications are needed to understand how the potential of FSTS outlined in this paper can be applied in these areas.

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