How do instructors understand unequal representation in STEM?

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While trends over the last few decades show increases in women and non-white scholars in STEM fields, there remains disparate attrition at different transition points within academia. The underrepresentation of certain demographic groups in STEM is broadly understood as rooted in systematic historical oppression and exclusion which continue their presence in various ways – but it is not clear how understood this is by faculty at large. To better understand faculty beliefs related to the (dis)advantagement of race-gender groups in STEM, we conducted a Latent Class Analysis on 945 responses from instructors of introductory chemistry, physics, and calculus courses at a variety of institutions across the United States. We then looked to see how those views relate to faculty support of policies and activities which might advance diversity and equity in postsecondary STEM education. Four clear patterns are discussed.

Keywords: Equity, instructor beliefs, DEI, STEM instructors

One symptom of the systemic inequities plaguing our society is that the race-gender demographics of STEM fields in the United States are markedly dissimilar from those of the country and the undergraduate student population. Though representational diversity is not equivalent to equity or justice, the persistent discrepancies in representation are certainly indicators of a larger problem. Trends over the last few decades show increases in women and scholars of color[1], with variation between different STEM fields (NCSES, 2021). However, there continue to be disparate attrition for women (Shaw & Stanton, 2012) and non-white (Shaw et al., 2021) scholars at different transition points within academia.

The underrepresentation of certain demographic groups is broadly understood as rooted in systematic historical oppression and exclusion which, while now ostensibly outlawed, continue their presence in various ways – but it is not clear how understood this is by most faculty. Current faculty are key actors within the broader educational system: they interact regularly with students, make decisions about who to mentor (and how), and have some say in policy decisions within their academic units. How they engage in these activities has the potential to impact recruitment and retention. While instructors may occupy a role in which they can support diversification of the fields and a shift toward more equitable systems, they may not be aware of this potential (Gandhi-Lee et al., 2017) or even the need for change – and in some cases may push back against efforts to advance diversity, equity, and inclusion. In order to better recruit faculty to the cause of advancing equity in higher education, we must better understand their current views and the organizational culture(s) in which they exist – parallel to the work our field has done to recruit instructors to use research-based instructional practices (e.g., Apkarian et al.,

[1] We note that gender is not a wo/man binary, that race is a fluid and complex social construct which should not be reduced to simplistic categorizations, and the intersectional nature of identity. However, we are limited in some respects by how these terms are used generally in society, federal databases, and prior research.

2021; Chowdhury et al., 2021; Johnson et al., 2018, 2019; Reinholz & Apkarian, 2018; Yik et al., 2022). This study takes a first step toward that end, reporting on a subset of:

1. *Classes (or patterns) of instructor beliefs related to the (dis)advantagement of race-gender groups in STEM which exist among current instructors; and*
2. *Relationships between class membership and support for activities in support of advancing DEI in postsecondary STEM contexts.*

Theoretical Background & Relevant Literature

We take the position that equity is a moral imperative, and that STEM, education, and academia are currently inequitable systems which need to undergo systemic cultural change. Faced with institutional inertia as well as complex logistical, economic, and political considerations, we look in the short-term to the role of faculty to support students and shift disciplinary culture to be more inclusive and equitable. In essence, faculty act as the ultimate gatekeepers of the disciplines, and their actions – influenced by their beliefs – have great power to support or constrain efforts toward diversifying and making equitable the STEM fields.

Among the indicators of inequity in STEM higher education is the race-gender imbalance in representation (Apkarian, in press; NCSES, 2021). Some of the immediate factors impacting students' intention to pursue STEM (e.g., recruitment) include existing interest in STEM, positive math and/or science identity, and academic preparation (Cribbs et al., 2015; Gandhi-Lee et al., 2017; Graven & Heyd-Metzuyanim, 2019; Langer-Osuna & Esmonde, 2017); of course, these are not equally accessible to, nor cultivated in, all students. Beyond recruitment, there are disparate rates of retention at various junctions along the path to a STEM career (Ellis et al., 2016; Hatfield et al., 2022; NCSES, 2021; Shaw et al., 2021; Shaw & Stanton, 2012; Wapman et al., 2022). Additionally, there are cultural systems, specific to mathematics and science. These include a racialized hierarchy of mathematical ability which generally manifests as an expectation that Asian (men) are 'too good' while those who are not White or Asian are 'not good enough' at mathematics (Martin, 2003; McGee & Martin, 2011; Shah, 2017, 2019). There are additional gendered norms and expectations, which often take the form of suggesting that women are not as capable of mathematical or scientific thought as men (Handley et al., 2015; Hottinger, 2016; Leyva et al., 2016). Of course, these are intersecting systems which produce intersectional experiences (Castro & Collins, 2021; Cech, 2022; Covarrubias, 2011; Gholson & Martin, 2019; Williams et al., 2014). These, and additional systems of inequity such as ableism (e.g., Annamma et al., 2013; Bettencourt et al., 2018; Taylor & Shallish, 2019) are often hidden behind a belief that STEM is insulated from racism and sexism, and is instead a true meritocracy (Au, 2013; Cislak et al., 2018; Handley et al., 2015; Liu, 2011; Sobuwa & McKenna, 2019).

While there exist a number of strategies employed by higher education institutions to try to acknowledge, mitigate, and/or address aspects of system inequity (e.g., affirmative action, and similar, policies for student admissions and faculty hiring; diversity statements), these are not uniformly supported by faculty nor is there unanimous consensus among STEM faculty that they have a personal responsibility to address inequities in their disciplines (Johnson et al. 2022). We take support for, and engagement with, policies and efforts to diversify STEM fields as aspects of faculty professional practice and, just as with other aspects of professional practice (e.g., instructional practice) we see faculty beliefs as both a key influence and a necessity for change.

Participants & Data Collection

Data come from a web-based survey of postsecondary instructors distributed in Fall 2020. Participants were instructors of introductory chemistry, physics, and calculus courses at a variety of institutions (including two-year colleges, four-year colleges, and universities). Each had completed a survey in 2019 regarding their instructional practices and factors impacting their pedagogical choices as part of a larger project; they were then invited to participate in this follow-up regarding their experiences with, and attitudes toward, DEI issues and initiatives in higher education. For the follow-up survey, we received 1064 responses from the 2229 invited to participate (47.7% response rate).

We focus this analysis on a series of questions related to beliefs about different race-gender groups and STEM. These items were designed to gauge whether instructors recognize the systemic advantages and disadvantages related to race and gender in the sciences as well as to gauge instructors' beliefs about various explanations for under-representation of demographic groups compared to white cisgender men. Previous analysis (Johnson et al., 2022) showed that, in the aggregate, many STEM instructors recognize relative systemic (dis)advantages based on racial and gender characteristics; few suggested variation in aptitude for STEM; responses were more mixed with regards to the distribution of opportunity and interest in the disciplines. It also revealed that instructors were more likely to support statements in support of DEI than affirmative action style policies. This analysis seeks to understand patterns within these responses in order to better understand clusters of attitudes and positions relevant for faculty support to advance equity and inclusion in STEM.

Latent Class Analysis

We employed *latent class analysis* (LCA) to identify potential groups or classes among our participants, which might drive patterns in their responses. LCA is a type of structural equation modeling used to identify groups (called latent classes) in multivariate categorical data. The data used for the LCA is the 22 items about (dis)advantage, opportunity, aptitude, and interest in STEM for different race-gender groups. In the survey items regarding (dis)advantage, respondents were presented with 8 race-gender pairs (Asian Women, Black Women, Hispanic/Latinx Women, White Women, Asian Men, Black Men, Hispanic/Latinx Men, White Men) and asked "From your perspective, do people from each of the following demographic groups receive a net systematic advantage or disadvantage due to their demographic characteristics in [your field]?" For the survey items regarding opportunity, aptitude, and interest in STEM, respondents were asked "More than half of the PhDs awarded in 2017 in mathematics and the physical sciences were received by white men. As compared to the majority group (white men), how much interest, aptitude, and opportunities do you think other groups have in [your field]?". They were prompted to respond with regard to the seven other race-gender pairs. Each of these 22 items had three response options, more/equal/less. We reduced the 1064 responses to 945 complete cases.

Multiple LCA models were built and tested; model selection involved inspection of model fit parameters and diagnostic criteria (Nylund-Gibson & Choi, 2018; Weller et al., 2020). Analysis was performed in RStudio using the poLCA package (Linzer & Lewis, 2011; R Core Team, 2022; RStudio Team, 2022). For $5 \leq k \leq 10$, 10 models of k-classes were generated using Monte Carlo Markov Chain methods. These models were then compared in terms of their model fit statistics, diagnostic criteria, as well as their interpretability considering existing theory and literature, as incongruent fit indices are common with such analyses (see Table 1 for model fit statistics.) This resulted in a choice of the eight-class model, which had the lowest BIC and highest BF. For this eight-class model, the minimum average latent class posterior probability is 0.940, well above the minimal threshold; entropy was 0.96, well above the .80 standard cut off; the smallest class is 2.8% of the sample population (Class 5); this is 26 individuals and may be admitted for analysis with caution.

Table 1. Evaluating class solutions.

Model	LL	AIC	BIC	G^2	X^2	BF
5	-13247.61	27083.22	28509.47	15075.2	4.4e+18	0.000
6	-12899.78	26505.57	28218.04	14379.54	1.6e+18	0.000
7	-12661.73	26147.46	28146.15	13903.44	2.9e+16	0.000
8	-12395.36	25732.71	**28017.62**	13370.69	**3.6e+15**	**>>15.00**
9	-12281.36	25622.73	28193.85	13142.7	8.3e+17	0.000
10	**-12066.67**	**25311.35**	28168.69	**12713.32**	1.16e+15	--

Note: LL – maximum log-likelihood; AIC – Akaike information criterion; BIC – Bayesian information criterion; G^2 – likelihood ratio/deviance statistic; X^2 – Pearson chi-square goodness of fit statistic for fitted vs. observed multiway tables; BF – Bayesian factor.

Model Description

Figure 1 shows the proportion of participants, in each latent class, who responded “more,” “equal,” or “less” to four key questions (divided by dashed lines) regarding each of the target race-gender groups; that is, the conditional probability of a participant selecting responses given that they are a member of a particular class. Note that the question at the bottom is the only one which includes White Men, because that’s the question about net advantage/disadvantage; the others are asked in reference to White Men (the dominant group). Moving upward, the second question related to *interest* to engage in the field; the third to *aptitude* for the field; the fourth (top) to *opportunity* in the field.

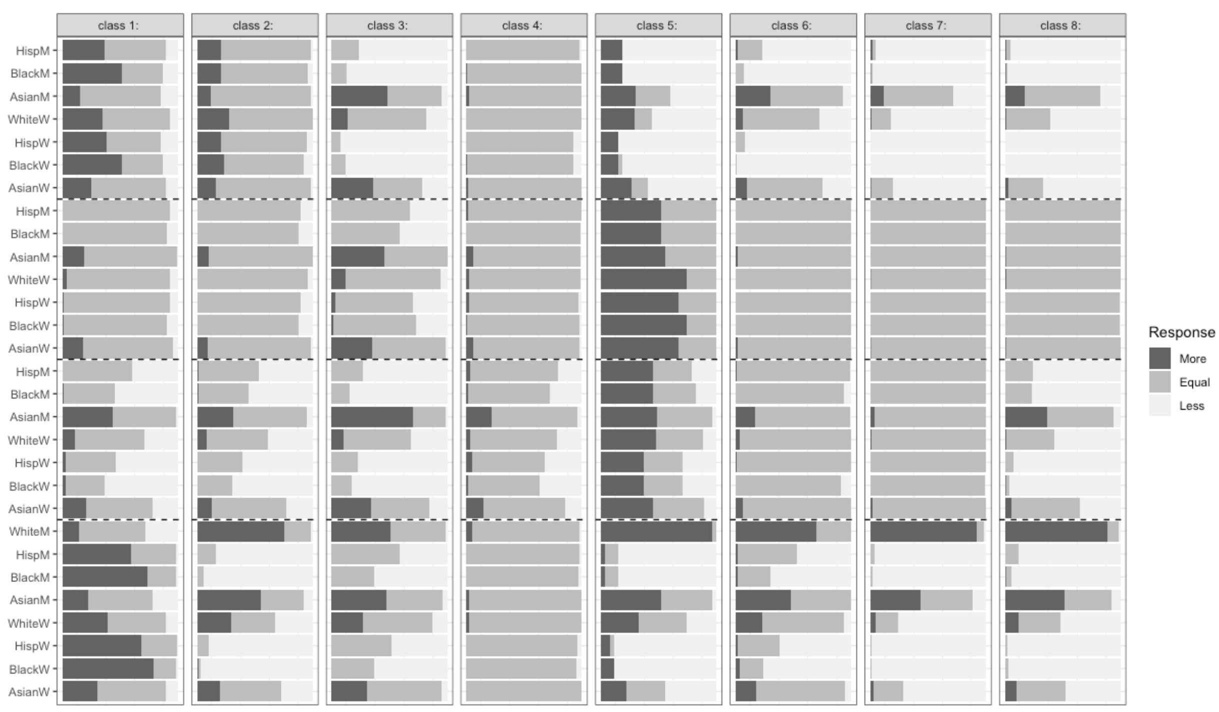

Figure 1. Conditional probabilities of answer choice selection based on class membership.

Model Interpretation

We anticipate that these profiles coincide with beliefs and actions which have direct impact on DEI issues and initiatives in higher education which is of great interest to our work. To that extent, we performed a series of Pearson's Chi-squared tests (with Bonferroni correction). Table 2 reports the results of these tests, as well as the cells in which standardized residuals (*sr*) had magnitude larger than 2, indicating that they are contributing to the statistical significance. This suggests that the model captures some variation in relation to faculty positions on DEI initiatives.

Table 2. Chi-squared tests

	χ^2	df	*p* adj	Contrib.
[A] *Do you, or would you, support AA-style policies in…*				
Student admissions	112.7	14	< 0.001	1, 3, 4, 7
Faculty hiring	132.5	14	< 0.001	1, 4, 7, 8
[A] *Do you, or would you, support DEI statements by…*				
Departments	134.3	14	< 0.001	1, 4, 7, 8
Institutions	135.4	14	< 0.001	1, 4, 7, 8
Professional societies	162.3	14	< 0.001	1, 4, 7
[B] Efforts to increase diversity are […] for my field	187.1	14	< 0.001	1, 3, 4, 7, 8
[C] I have personal responsibility to address DEI	73.01	7	< 0.001	1, 4, 6, 7, 8

N varies across tests by question response rate. All p-values adjusted for repeated testing. [A] Response options were yes; no; no opinion; [B] Response options were beneficial; detrimental; neither. [C] Response options were condensed to Agree (Strongly Agree; Agree); Disagree (Strongly Disagree; Disagree).

Discussion of Results

Classes 1, 4, 7, and 8 contribute the most consistently to associations between latent classes and additional characteristics, account for about 2/3 of the participants, and are easily interpretable within the extant literature. Therefore, we focus on them and suggest that additional, clearer data is needed to understand other patterns of belief. We name these four based on their most distinctive analysis patterns: Class 1 becomes *Advantage to Underrepresented Racial Groups*; Class 4 becomes *Race-Gender Equity in STEM*; Class 7 becomes *Opportunity and Advantage for White and Asian Men*; Class 8 becomes *Opportunity, Interest, and Advantage for White and Asian Men*. We discuss the belief patterns of each group, as well as the relationship between group membership and positions on DEI initiatives.

Class 1: Advantage to Underrepresented Racial Groups

This group of 73 represents 7.8% of the survey respondents. The group presents an inverted pattern of advantage compared to the other groups (see Figure 1); the majority of this group identify Black and Hispanic men and women as having a systemic advantage in STEM and Asian and White men and women as having neither an advantage nor disadvantage. More than a quarter of this group identify White men as *disadvantaged*. As compared to White men, this group suggested that Black men and Women have more opportunity to do science and mathematics, with other groups considered more equal. In terms of aptitude, the majority of this group (as with most groups) viewed everyone as having equal aptitude (though the distribution of the minority is interesting as well). In terms of interest, however, we see that this group believes that some of those least represented are also less *interested* in STEM than White men.

Considering the other questions (Table 2), this group were less likely to support affirmative-action style policies (admissions *sr* = -4.6; hiring *sr* = -5.0) and DEI statements (department *sr* = -7.3, institution *sr* = -7.9, society *sr* = -8.9); more likely to say that efforts to diversify STEM are detrimental for the field (*sr* = 7.8); less likely to say that they have personal responsibility to address inequities (*sr* = -5.7). These responses may reflect some kind of 'reverse discrimination' mentality, in which those with privilege view any reduction in their status (or increase in others' status) as an attack, rather than a leveling.

Class 4: Race-Gender Equality in STEM

This group includes 107 people, or 11.4% of the sample. The vast majority (93-100%) of the members of Class 4 responded that each race-gender group receives *neither a systematic advantage nor disadvantage* due to their demographic characteristics. They report similarly consistent and dominant views that all groups have equal opportunity (91-100%) and aptitude (93-99%). The majority (61-76%) of this group report that all race-gender groups have equal interest in STEM. (See Figure 1).

Like Class 1, members of Class 4 were less likely to support affirmative-action style policies (admissions *sr* = -5.4; hiring *sr* = -6.7) and DEI statements (department *sr* = -5.1, institution *sr* = -4.7, society *sr* = -5.9) and more likely to disagree that they have personal responsibility to address inequities (*sr* = -5.3). They were also less likely to say that efforts to increase diversity are beneficial (*sr* = -7.6), but unlike Class 4 they are more likely to say that these efforts are neither beneficial nor detrimental (*sr* = 8.0) rather than to identify them as detrimental for their field (*sr* < 1).

Class 7: Opportunity and Advantage for White and Asian Men

Class 7 is the largest group of them all, including 283 (30%) of the survey participants. The vast majority (96-100%) of this group indicated that Black and Hispanic/Latinx men and women receive a systemic disadvantage in STEM; a substantial majority indicated that Asian women (71%) and white women (76%) receive a systemic disadvantage. For Asian men, the story was rather split between neutral and advantage. In contrast, 93% of this group indicated that white men receive a systemic advantage. (See Figure 1).

Members of Class 7 were more likely to support affirmative-action style policies (admissions *sr* = 7.6; hiring *sr* = 6.9) and DEI statements by departments (*sr* = 6.9), universities (*sr* = 6.1), and professional societies (*sr* = 5.9); more likely to report that efforts to encourage diversity are beneficial for the field (*sr* = 6.5). In all these responses, members of this group were less likely to hold an opposition *or* neutral stance. This group was also more likely to agree that they have personal responsibility to address inequities (*sr* = 3.9).

Class 8: Opportunity, Interest, and Advantage for White and Asian Men

Class 8 included 158 participants (17% of sample). This group is very similar to Group 7 in their responses to the advantage, opportunity, and aptitude questions, but differs when it comes to the question about interest levels. While members of Group 7 unambiguously noted that all groups have equal interest in STEM, Group 8 is more complicated. Almost all of this group (93-96%) reported that Black and Hispanic women are less interested in STEM than White men; roughly ¾ of the group suggested that Black and Hispanic men are less interested; the majority (57%) suggest that White women are less interested compared with White men. Regarding Asian men and women, we see that the majority (58-59%) report that Asian men and women have the *same* level of interest as White men – but the bulk of the others diverge. A little more than a third (35-37%) of the group thinks that Asian women are less interested, but Asian men are *more* interested than White men. (See Figure 1). This reveals nuance and complexity within instructors' beliefs, evidencing the intersection of racialized and gendered hierarchies in STEM.

Chi-squared testing revealed a bit less about members of Class 8 than Classes 1, 4, and 7. They were less likely to oppose affirmative-action style policies in faculty hiring (*sr* = -2.1), but not more likely to support (*sr* <1); they did not contribute to the significance of responses to affirmative-action in student admissions. Similarly, they were less likely to oppose DEI statements by departments (*sr* = -2.3) and institutions (*sr* = -2.1) but not more likely to support – and they did not contribute to the significance regarding DEI statements by professional societies. They did not contribute to the significance of the personal responsibility question. However, they were strongly overrepresented in saying that efforts to encourage diversity are beneficial (*sr* = 4.1) and were less likely to say these efforts were detrimental (*sr* = -2.1) or not to have an opinion (*sr* = -3.4).

Concluding Remarks

This report is a very brief investigation of STEM instructors' views related to race and gender in STEM, as well how those views relate to activities which might advance diversity and equity in postsecondary STEM education. We detected eight profiles within our sample of 945 faculty. The four detailed here suggest that there are differing views on systemic advantages in relation to race and gender; there are also differing views of potential causes.

The prevailing response pattern found in Class 1 appears to aligns with beliefs that reparative efforts are 'unfair,' which have manifested in court cases opposing affirmative action[2] and may reflect how a loss of privilege can feel like oppression (Klein, 2020; Murrell & Jones, 1996; Yosso et al., 2004). The belief pattern reported by Class 4 is consistent with (inaccurate) beliefs about STEM and academia as race-gender-neutral spaces which function as meritocracies and do not perpetuate societal inequities. The response distributions in Classes 7 and 8 have similar response patterns with regards to systemic advantages and disadvantages; they also report similar patterns in terms of opportunity and lack thereof. However, while nearly all respondents in Class 7 report that all race-gender groups have equal interest in STEM, respondents in Class 8 indicated that they view the race-gender groups that have been systemically disadvantaged also have *less interest* in STEM.

This kind of nuance, even among those who generally recognize the presence of systemic race-gender inequities in STEM, are indicative of the nuances needed to enact systemic change toward more equitable systems. Additional research is needed to ascertain nuances of belief and how to leverage and/or change those beliefs. For example, how do members of Class 8 come to believe that Black and Hispanic men and women have less interest in STEM than Asian and White men and women – and how might that impact their views on who has opportunities to do STEM and net systemic advantages and disadvantages? There are many limitations to this study, but none which suggest that there are *not* such beliefs among instructors – particularly given the extant literature.

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[2] There are some legitimate criticisms of affirmative action policies and their implementation, although such policies have had some positive impacts. We omit a full discussion.

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