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Gender demographics of departmental seminar speakers reflect gender disparities of faculty hosts

Rachel A. Hutto[1*†], Lisa Voelker[2*†], Jacob J. O'Connor[1], Lucy H. Lin[3], Natalia Mesa[4] and Claire Rusch[2]

Abstract

Increasing access, representation, and retention of underrepresented groups is essential across academia. Invited speaker seminars are common practice in academic science departments and serve to disseminate research, establish connections and collaborations, advance faculty careers, and connect trainees to mentors outside of departmental faculty. Thus, lack of representation among seminar speakers can affect both faculty and trainee professional development. This study characterizes gender demographics of seminar speakers across science departments at an R1 institution for the years 2015–2019, using pronoun usage as a proxy for gender identity. We found that most faculty and invited speakers were male, and few were female or nonbinary. The percentage of female and nonbinary invited speakers increased from 2015–2019 along with the percentage of female and nonbinary host faculty. Overall, male faculty hosted fewer female and nonbinary speakers than their female and nonbinary faculty colleagues. This study provides evidence for a correlation between faculty identity and the scientists they host at their department and motivates further studies investigating this relationship at other R1 institutions and institution types.

Keywords: Graduate, Seminar, Colloquium, Gender Identity, STEM, Faculty development, Representation, R1 institutions, Colleges

Introduction

Despite efforts to increase representation, inclusion, and retention of underrepresented groups in science, disparities persist. Many studies have covered discrimination, harassment, and other inequities (Cech & Waidzunas, 2021; Johnson et al., 2018; White-Lewis, 2020), microaggressions and subtler majority-default behaviors (Cheryan & Markus, 2020), the value of safe in-group spaces (Kirby et al., 2020), and numerous other aspects of underrepresented groups' experiences in science. On the axis of gender identity, there is ample evidence that female scientists face disadvantages compared to their

male colleagues. Women are underrepresented across career stages in many fields of STEM due to barriers created by harassment and discrimination (Hill et al., 2010). Female scientists face funding gaps compared to their male peers, and when examining funding programs that explicitly focus on the potential and caliber of the PI rather than the merit of the project this funding gap widens significantly (Witteman et al., 2019). When the same professor uses different gender identities in an online classroom environment, they receive weaker teaching evaluations when identifying themselves as female rather than male (MacNell et al., 2015). In terms of hiring, PIs are more willing to hire and mentor male laboratory managers and male faculty applicants receive stronger letters of recommendation than female applicants (Moss-Racusin et al., 2012; Schmader et al., 2007).

There is a paucity of research on representation of transgender or nonbinary individuals in science,

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Hutto *et al. Discip Interdscip Sci Educ Res*   (2022) 4:21

Page 2 of 12

complicated by a lack of demographic data in the broader population and the difficulty of studying small populations. There is strong evidence that trans and nonbinary individuals in STEM face discrimination and harassment (Cook et al., 2020; Siegel, 2019) and that LGBT STEM professionals are more likely to experience career limitations and express a desire to leave STEM than their non-LGBT peers (Cech & Waidzunas, 2021). It is also important to note that transgender men may still experience barriers to participation in science due to transphobia. It is important that future research and policies more explicitly consider nonbinary and transgender individuals in addition to focusing on cisgender women in order to achieve gender equity.

The practice and impact of departmental seminars

Departmental seminars are ubiquitous across academia and have been since the nineteenth century (Karlsohn, 2016). Though the exact form differs between institutions and departments, in modern STEM departments seminars usually consist of regularly scheduled hour-long presentations from scientists about their research. Some departmental seminar series are focused on presentations from students and faculty members, serving as a way to update the whole department on current research and providing trainees the opportunity to practice presenting information and receiving feedback. We are primarily interested in studying seminar series that consist of research talks from scholars outside of the hosting department.

Invited speaker seminar series serve many purposes, mimicking at a small scale many of the functions of a larger academic conference. They allow department members to learn about current research occurring in their field, make connections with scholars outside of their institution, establish new collaborations, and expose trainees to potential research avenues and scientific mentors. For trainees, invited seminars play a role in shaping their understanding of who is important and valued in their field. This impact may be especially important to consider given the frequency and ubiquity of departmental seminars when compared to academic conferences: while a trainee may attend a few conferences a year, they are likely to see invited seminar speakers on a regular basis and thus the seminars play a role in illuminating the culture of their institution. For the speaker, seminars offer an opportunity to share their work in a professional setting, receive feedback, and expand their network. Seminars also serve as a venue for departments to evaluate candidates for positions within a department. As such, departmental seminars serve as important ways for academics to advance their careers, and disparities in demographics of invited speakers may reflect and/

or exacerbate existing inequalities in a field. Despite the ubiquity of seminars and colloquia in academic departments, few studies have been devoted to the practice, particularly examining the demographics represented. However, scholarship has illuminated a gender gap in invited speakers at academic conferences across STEM disciplines (Casadevall & Handelsman, 2014; Ford et al., 2018; Kalejta & Palmenberg, 2017; G. Martin, 2015; Mehta et al., 2018b; Schroeder et al. 2013a, 2013b).

Previous studies have examined gender and racial disparities in departmental seminar speakers through the lens of a specific year or department. A multi-institution and multi-field study conducted for the 2013–2014 academic year demonstrated that male academics were more likely to present at departmental seminars than female academics, even when correcting for differing sizes of the gender pool in the given field (Nittrouer et al., 2018). This effect was not attributable to male faculty placing higher importance on giving seminars or female faculty declining seminar invitations at a higher rate than male faculty; in fact, a predictor for higher female representation in seminar speakers was simply having a female colloquium committee chair, a finding that mirrors similar trends at academic conferences (Casadevall & Handelsman, 2014; Ford et al., 2018; Kalejta & Palmenberg, 2017; G. Martin, 2015; Mehta et al., 2018b; Schroeder et al. 2013a, 2013b). A more recent study has examined the interplay of gender and race in seminars in a single department, demonstrating a lack of gender and racial equity. Notably, all female invited speakers were white, underscoring the interplay of multiple marginalized identities (Hagan et al., 2020). Both of these departmental seminar studies assigned individuals' gender identities from photos, CVs, and/or personal knowledge.

Science identity theory

We chose to examine representation in seminars through the lens of science identity theory. "Science identity" is the conceptualization of oneself in relation to science (Brickhouse et al., 2000). In the framework proposed by Carlone and Johnson, an individual's science identity is affected by both their own recognition of themselves as a "science person" and the recognition by meaningful others that they are a "science person" (Carlone & Johnson, 2007). In particular, the recognition by others dimension interacts with other identities such as race, ethnicity, and gender. Science identity has been found to be an important factor in the pursuit of science as career and persistence in science (Chemers et al., 2011; Stets et al., 2017; Vincent-Ruz & Schunn, 2018). Importantly for academic science, science identity has a positive effect on graduate school matriculation and is a predictor for graduate

Hutto *et al. Discip Interdscip Sci Educ Res*   (2022) 4:21

Page 3 of 12

student intentions to stay in science (Estrada et al., 2019; Merolla & Serpe, 2013).

Science identity can be affected by several internal, social, and environmental factors. One factor is that students seeing science professionals ("role models") that reflect students' other, non-science identities may enhance their own science identity. Regarding gender identity, female role models have been shown to positively impact the science identity of female students at the middle school level (Merritt et al., 2021), high school level (Chen et al., 2020), and undergraduate level (Stout et al., 2011; Young et al., 2013). However, it should be noted that some studies have failed to detect a similar effect (Bamberger, 2014; Conner & Danielson, 2016).

The relevance of science identity to academic seminars is two-fold. For one, seminar speakers can serve as scientific role models for graduate students and postdocs, potentially increasing science identity among trainees. Secondly, an invitation to speak at a seminar can serve as external recognition for postdocs and early-career faculty, strengthening their own science identity.

Study design

The aim of this study was to examine the gender demographics of seminar speakers in across multiple science departments at a large, R1 university over a recent five-year period and examine any correlations between the identity of speakers invited and the faculty that invited them. This study serves to fill a knowledge gap in the literature by examining trends over time in seminar speaker representation and may be generalizable to institutions with similar departmental seminar practices. Additionally, this study explicitly includes individuals who identify as nonbinary, a classification for a variety of gender identities that are not exclusively male or female. The experience of nonbinary scientists in academia is an under-researched area and this study attempts to add to this growing body of literature. We used pronoun usage in professional-facing materials (see methods) as a proxy for gender identity rather than previously used methods of assuming identity from photos and names to reduce investigator bias and more accurately reflect an individuals' gender identity. We found these previously used methods of visual determination based on photos or assumptions based on names to be problematic as both rely primarily on stereotypes. For all individuals, but especially for those who identify outside of the typical female/male binary, external gender presentation can diverge significantly from the categories of traditionally "masculine" or "feminine", making determination difficult. Furthermore, even someone who may appear to be typically feminine or masculine may not actually identify as such. While relying on names may seem to be less bias-prone than making determination based on photos, a number of names are ambiguously gendered. Furthermore, instances of cultural difference between the subject and coder may make identification of the gendered nature of names especially challenging given the coder may not be familiar with gender categories in other cultures. We believe that while relying on pronouns is not perfect (see discussion), it is less reliant on stereotypes and investigator bias.

Research questions

First, we considered the question of whether gender demographics of invited seminar speakers reflected graduate student demographics or if they mirrored the demographics of the faculty inviting them. We began with this first question because graduate student science identity (and retention in science) can be influenced by positive role models that share their gender identity. We hypothesized that seminar speakers would be a higher percentage male than graduate students and faculty based on previous work showing that male seminar speakers are overrepresented across disciplines (Hagan et al., 2020; Nittrouer et al., 2018). Notably, this previous result was observed even when controlling for the available pool of faculty and despite no differences between male and female faculty in turning down speaking invitations (Nittrouer et al., 2018).

Our next research question was if representation of female and non-binary seminar speakers and faculty hosts had changed over time. We hypothesized that any trends in overrepresentation of male seminar speakers was not static and could be changing based on previously published observations of 1) increased representation of women in science from 2015–2019 (National Center for Science and Engineering Statistics (NCSES), 2018, 2021) and 2) increased scrutiny of gender representation in other academic practices such as conference speakers and speaker selection committees (Casadevall & Handelsman, 2014; Ford et al., 2018; Kalejta & Palmenberg, 2017; G. Martin, 2015; Mehta et al., 2018b; Schroeder et al. 2013a, 2013b). Based on this, we hypothesized that more recent years would have higher representation of female and nonbinary speakers and faculty hosts.

We next aimed to investigate the relationship between faculty host gender and the speakers they host for seminars. Speaker selection is likely influenced by many factors which could include research relevance, perceived expertise, social connections, and implicit bias. We hypothesized that the gender of the host could interact with some of these possible factors and a difference in invited speakers would be observed between male, female, and nonbinary faculty. We also aimed to assess whether any identified trends among faculty gender

identity and invited speaker identity were replicated among trainees (graduate students and postdocs).

Methods

Historical seminar data (including invited scientist speakers and departmental hosts) were collected across science departments at a single R1 institution from public archives of departmental websites. The R1 institution is located in the Pacific Northwest with an undergraduate population of ~30,000 and a postgraduate population of ~16,000. The science departments included in this study were Biology, Biochemistry, Chemistry (Inorganic), Computer Science and Engineering, Physiology and Biophysics, Pharmacology, and Microbiology. These 7 departments were chosen from the other 26 science departments for hosting regularly scheduled invited speakers and their availability of historical data. They represent 278 faculty members spanning multiple colleges within the university (College of Arts and Sciences, Paul G. Allen School of Computer Science & Engineering, and School of Medicine). Data were collected from academic calendar years 2015–2019.

Gender identity was approximated by pronoun usage in professional-facing written materials (speaker description for seminar, speaker's official departmental website or other professional websites authored by the speaker, Wikipedia, press releases, and news articles). Social media or other non-professional websites like ratemyprofessor.com were not used. Gender identity was linked to pronoun usage as follows: "he/him" as male, "she/her" as female, "they/them" or other pronouns as nonbinary, and a lack of suitable professional materials containing pronouns as "unable to determine". Notably, this system misclassifies anyone identifying as nonbinary that uses he/him or she/her pronouns, anyone using they/them pronouns that identifies as male or female, and anyone that does not use pronouns that reflect their gender identity in a professional setting. Additionally, journalists or other content creators may not always ask about pronoun usage, leading us to misclassification. When pronoun usage differed between materials (an infrequent occurrence), instances where the speaker self-identified (i.e., departmental or personal websites) were used. Each pronoun assignment was performed independently by three different authors of this paper. The Fleiss' Kappa for inter-rater reliability was 0.93 with a 95% confidence interval of 0.92–0.95, indicating high agreement in gender assignments between raters. Any discrepancies were flagged for review then later resolved by discussions among the three coders until a consensus could be reached. Faculty gender identity was ascertained using the same metric as seminar speaker gender identity. Faculty totals represent tenure-track faculty, but non-tenure track faculty were also included in a given department if that category was also involved in hosting that department's seminars.

For specific individual trainees that served as seminar hosts (graduate students or postdoctoral scientists), the same method of gender identification was used. Often, trainee invites were from a group (denoted as "Graduate Students" or "Postdocs" as the host); trainee invitations were not included in analysis of faculty invitations (Figs. 1, 2 and 3) but analyzed separately as trainee invitations (Fig. 4).
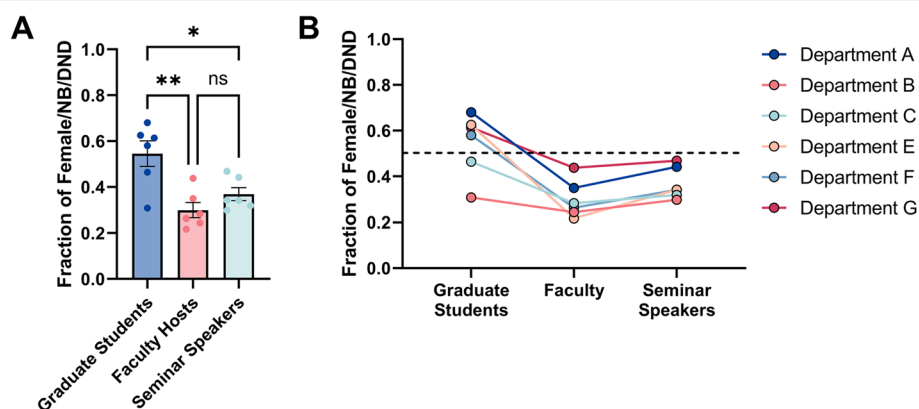
Fig. 1 Similar to faculty gender distribution, invited speakers were majority male. **A** The fraction of students, faculty, and seminar speakers that were identified as female, nonbinary (for faculty and seminar speakers), or did not disclose identity (for graduate students). Department D is not included in this comparison due to a low number of direct admits to the program ($n \leq 4$). *$p < 0.05$, **$p < 0.01$, and ns = not significant using a one-way ANOVA with Tukey's test for multiple comparisons. $N = 6$ departments. **B** Disaggregated data from A, with lines connecting each individual department's demographics. For all departments, the fraction of female/DND students was higher than female/nonbinary faculty and seminar speakers. $N = 6$ departments

Hutto *et al. Discip Interdscip Sci Educ Res*   (2022) 4:21

Page 5 of 12
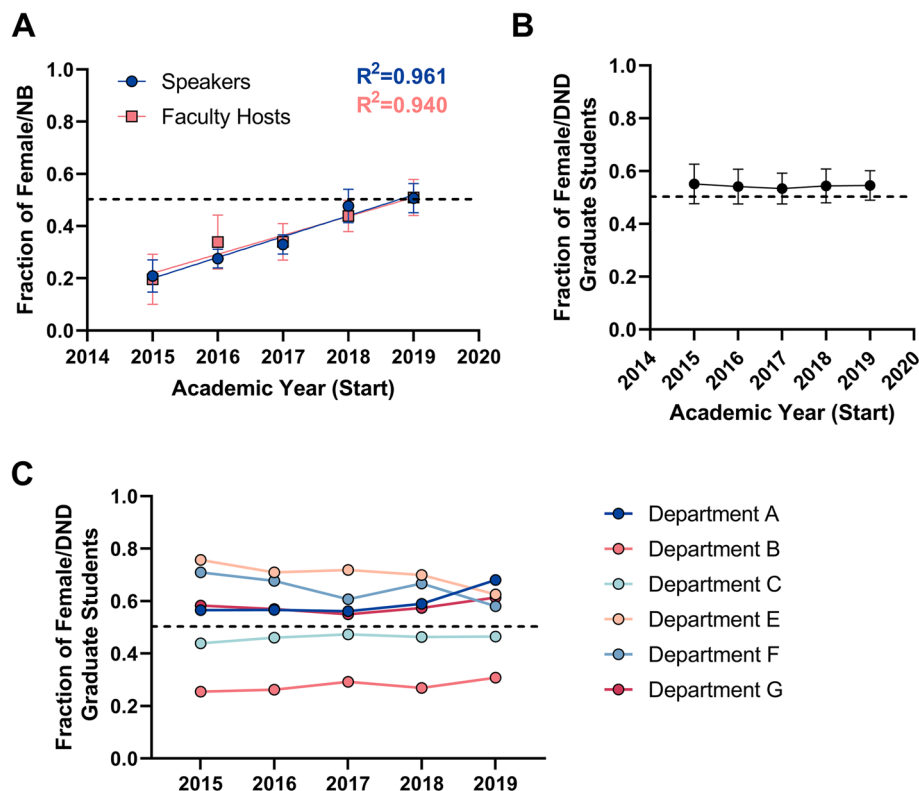
Fig. 2 While graduate student gender demographics remained steady from 2015–2019, the fraction of female and nonbinary seminar speakers and faculty hosts has increased. **A** A simple linear regression was performed using departments A, B, C, D, E, and G for each year. Departments with $n \leq 10$ for all years studied were excluded from analysis (Department F). The slopes of the linear fits for both speakers and faculty hosts were significantly non-zero ($p < 0.0001$ for speakers, $p = 0.008$ for hosts). Linear regression fit for speakers $R^2 = 0.481$, linear regression fit for faculty hosts $R^2 = 0.241$. Error bars represent the standard error of the mean. $N = 6$ departments. **B** Graduate student gender demographic data collected in the fall quarter of each academic year for departments A, B, C, E, F, and G (Department D is not included in this comparison due to a low number of direct admits to the department, $n \leq 4$). Data plotted as the fraction of students indicating "female" or did not disclose their gender identity (Female/DND), error bars represent standard error of the mean. $N = 6$ departments. **C** Data from B disaggregated by department. While the mean fraction of students identifying as female or choosing not to disclose their gender identity varies between departments, the fraction for each department has remained steady from 2015–2019. $N = 6$ departments

For seminar speakers and faculty that lacked appropriate materials for gender classification (labelled as "unable to determine" or "UNK"), we elected to exclude these from analysis. It is possible that a lack of available materials (such as press releases and news articles) could have some relationship to gender identity, and we did not want to skew our analysis by including these in any of the categories.

Graduate student gender identity was self-reported by students and collated by the R1 institution each fall quarter to reflect the current population of students in a given department. The gender responses included in this report were "Male", "Female", and "None indicated/Did not disclose". Notably, this classification excludes and masks any students identifying as nonbinary or any other descriptions of gender. Both the faculty classification system and the graduate student self-reporting criteria do not distinguish between cisgender and transgender individuals.

Sources for determination of faculty gender identity, speaker gender identity, and job talk status were all publicly available. All graduate student data was aggregated and obtained as de-identified data, with no way for investigators to re-identify the data. Thus, this study did not involve human subjects under the Common Rule and was not submitted to an IRB for consideration.

Data analysis, statistics, and visualization were performed using GraphPad Prism 9. Data are reported in-text as mean ± standard error unless otherwise noted.

Results
Gender demographics in seminar speakers, faculty, and graduate students
Combined data from all departments analyzed over the period of 2015–2019 showed that for graduate students, faculty, and seminar speakers the majority-represented gender identity is male (Table 1). To preserve anonymity

Hutto *et al. Discipl Interdscip Sci Educ Res*   (2022) 4:21

Page 6 of 12
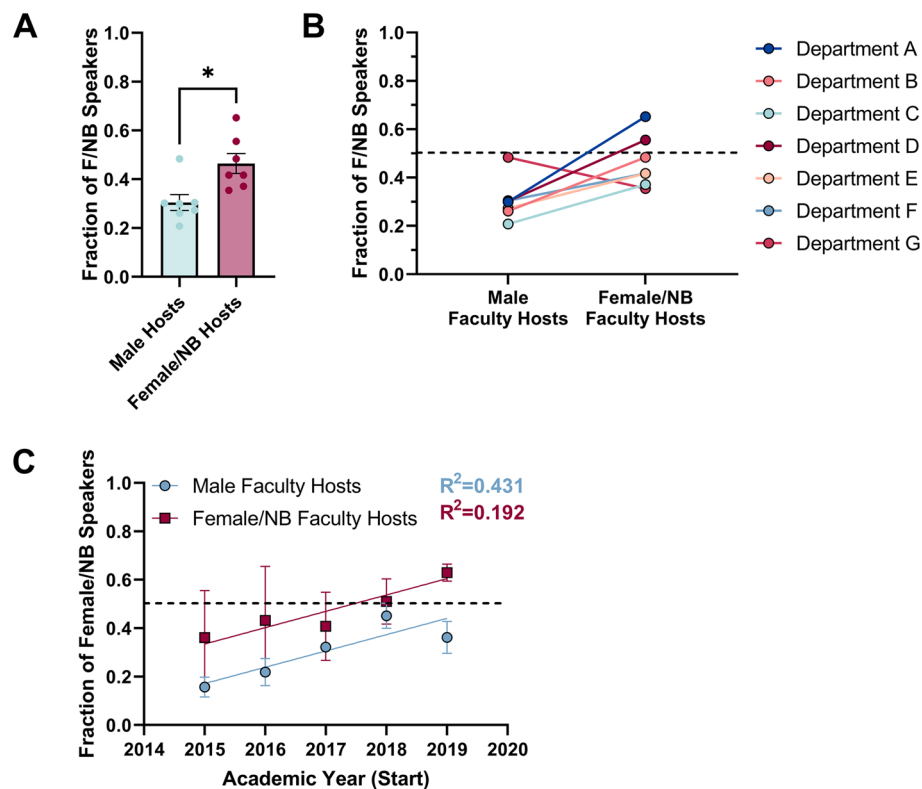
Fig. 3 Female and nonbinary faculty invited higher fractions of female and nonbinary speakers. **A** Aggregated data of seminars conducted in 2015–2019, categorized by whether the host faculty member was identified as male or female/nonbinary (Female/NB). Female and nonbinary faculty invited higher fractions of female and nonbinary speakers across nearly all departments. *$p < 0.05$ using a Paired t-test. $N = 7$ departments. **B** Data from A disaggregated by department. In all departments but department G, female/nonbinary faculty invited a greater fraction of female/ nonbinary speakers than male faculty in the same department. $N = 7$ departments. **C** Fraction of Female/NB invited speakers in a given academic year, disaggregated by host gender. A simple linear regression was performed using the mean across departments for each year. Both male hosts and female/NB hosts show an apparent increase in fraction of female/NB invited speakers over time, with female faculty consistently inviting a higher percentage than male faculty. Plotted points represent the mean of all departments, and data for a given year were only included if n $\geq$ 6. Linear regression fit for male faculty hosts $R^2 = 0.4311$ and for female faculty hosts $R^2 = 0.1924$. The difference in the intercepts was significant, $p = 0.0016$. Error bars represent the standard error of the mean. $N = 6$ departments
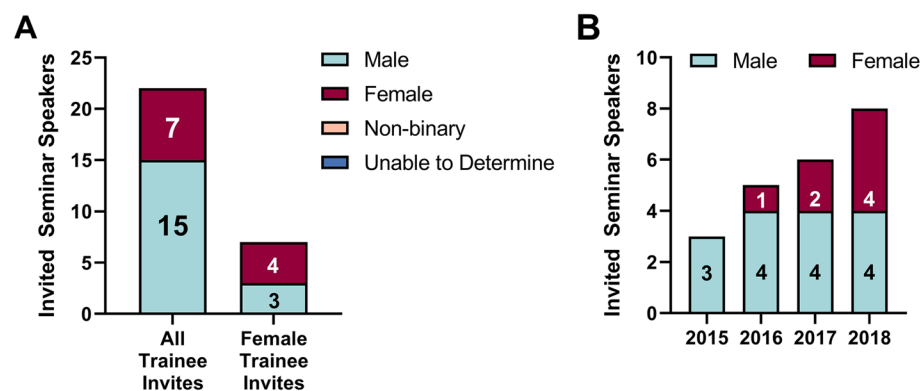
Fig. 4 Trainee-hosted seminars mirror trends observed in faculty-hosted seminars. **A** Invited seminar speakers binned by total trainee invites across all departments (individual and group invites) and invites from individual female trainees. No individual nonbinary graduate students were identified in the sample of trainee hosts. Overall trainee invites included a greater share of male speakers (68.2% male) than individual female trainees, whose invitations were 57.1% female. $N = 22$ total invitations. **B** Trainee invites stratified by academic year (start). The number of yearly trainee invites increased over the years studied, as did the proportion of female invited speakers for each year. $N = 22$ total invitations

Table 1 Breakdown of gender distribution among faculty, graduate students, and invited seminar speakers for each department studied

Department	Faculty (2019)				Graduate Students (2019)			Seminar Speakers (2015–2019)			
	M	**F**	**NB**	**UNK**	**M**	**F**	**DND**	**M**	**F**	**NB**	**UNK**
A	13	6	1	2	16	34	0	72	57	0	1
B	59	19	0	0	202	87	3	120	51	0	0
C	33	13	0	1	114	97	2	47	22	0	2
D	27	8	0	3	no data			53	25	0	4
E	14	5	0	2	13	18	0	48	25	0	1
F	18	5	0	0	9	15	0	29	15	0	0
G	27	19	2	1	22	34	1	43	37	1	1
Total	**191**	**75**	**3**	**9**	**376**	**285**	**6**	**412**	**232**	**1**	**9**
Percentage of Total	**71.0**	**27.9**	**1.1**	**X**	**56.3**	**42.7**	**0.9**	**63.9**	**36.0**	**0.2**	**X**

M male, *F* female, *NB* nonbinary, and *UNK* unable to determine. Individuals that did not have suitable materials containing pronouns (UNK) were excluded from the dataset. Graduate student data was not compiled for department D, which has a very low number of direct admits ($n \leq 4$)

for the limited number of nonbinary individuals ($n=3$ faculty and $n=1$ seminar speaker) and students that did not disclose gender identity ($n=6$), these individuals were not analyzed separately and instead were combined with female individuals for analysis, representing gender identities that are not part of the majority demographic (male). The implications and effects of this choice on data interpretation are explored in the discussion. As a whole, graduate students were found to have a significantly higher fraction of individuals identifying as underrepresented genders than faculty or seminar speakers ($54.5 \pm 5.6\%$ female/did not disclose graduate students, $29.9 \pm 3.3\%$ female/nonbinary faculty, and $36.7 \pm 2.8\%$ female/nonbinary seminar speakers, Fig. 1A, Figure S1). Gender demographics for individual departments, which were anonymized as Departments A-G due to their small size, are shown in Fig. 1B. Every department had a higher fraction of female/did not disclose graduate students than the faculty and seminar speakers in that department. The difference was smallest for department B, which had a much smaller fraction of female/did not disclose graduate students than the other departments studied.

Temporal trends in gender demographics
The percentage of seminar speakers of underrepresented genders (female and nonbinary) were calculated for each department and binned by academic year, revealing an increasing fraction of underrepresented speaker genders from 2015–2019 (Fig. 2A, blue trace, $R^2 = 0.481$, $p < 0.0001$ using simple linear regression). To assess other factors that may also change over the years studied, we calculated the percentage of seminars hosted by female and nonbinary faculty across the same timeframe.

This showed a similar trend to invited speakers, with an increasing fraction of underrepresented faculty hosts from 2015–2019 (Fig. 2A, pink trace, $R^2 = 0.241$, $p = 0.008$ using simple linear regression). No significant differences in slopes ($p = 0.773$) or intercepts ($p = 0.889$) were detected between the linear fits of F/NB speakers and faculty hosts over time. Gender demographics among invited speakers and faculty hosts were compiled by department and year in Table S1; seminars without single faculty hosts (n/a) were excluded from the host analysis and individuals for which gender was unable to be determined (UNK) were excluded from totals when calculating percentages. Graduate student gender demographics did not appreciably change during this time period; while considerable variation in gender demographics between departments was observed, these essentially remained constant for each department from 2015–2019 (Fig. 2B, C and Figure S2).

Correlation of speaker demographics with host demographics
Temporal trends in Fig. 2A suggest both the fraction of female and nonbinary seminar speakers and the fraction of seminars hosted by female and nonbinary faculty significantly increased over the years 2015–2019. To further assess this relationship, we binned seminars by faculty host gender (male faculty vs. female and nonbinary faculty) for each department. We found that female and nonbinary faculty invited higher fractions of female and nonbinary speakers ($46.4 \pm 4.1\%$ among female and nonbinary faculty hosts and $30.2\% \pm 3.3\%$ among male faculty hosts, $p = 0.0307$ using paired t-test, Fig. 3A). By disaggregating the data and examining each department,

we found that only in Department G did male faculty hosts invite a greater fraction of female and nonbinary speakers (Fig. 3B).

To see if correlation between host gender and invitee gender changed over time, we examined the fraction of female and nonbinary invited speakers by host gender for each academic year (Fig. 3C). Simple linear regression analysis revealed an increasing fraction of non-male invites over time among male faculty hosts ($R^2 = 0.4311$, $p = 0.0004$). Significant changes over time were not detected among female/nonbinary faculty hosts ($R^2 = 0.192$, $p = 0.0687$), but comparison of linear modeling of female/nonbinary faculty hosts to male hosts revealed consistently more invites of non-male speakers among female/nonbinary faculty than their male faculty counterparts ($p = 0.0016$ for difference in intercepts, Figure S3). For a given year, data points were only included in departments with at least $n = 6$ hosts; few departments had at least 6 female faculty hosts in early years of the analysis (see Fig. 2A). A full breakdown of which departments met the threshold for analysis for each given year is provided in Table S2.

We also examined the number of times each individual faculty in each department served as a host to assess whether there were differences according to faculty gender. While we found the number of invites for individual faculty varied widely from department to department, we detected no significant differences attributed to faculty gender (2-way ANOVA, department factor $p < 0.0001$, gender identity factor $p = 0.4546$, $p > 0.5$ for all Sidak's multiple comparisons within each department, Figure S3A).

Demographics of seminar speakers hosted by trainees

We also assessed seminars hosted by trainees, which we defined as graduate students and postdoctoral scientists. These results were analyzed by binning the data across all departments due to the low number of seminars hosted by trainees. We found that male seminar speakers made up the majority of trainee-hosted seminars (68.2% male, Fig. 4A). Some seminars were hosted by individual graduate students/postdocs rather than a group invitation, and by using the same criteria for gender coding as faculty we found that individual female and nonbinary trainees invited a greater fraction of female seminar speakers (57.1% female, Fig. 4A). By breaking down these invites by academic year, we found that along with an increasing number of trainees hosting seminar speakers there was an increasing fraction of female invited speakers over the time period studied (Fig. 4B).

Discussion

Summary of findings

By analyzing seminar speaker gender demographics across multiple science departments at a single institution, we were able to show that over a five-year period (2015–2019) male speakers gave nearly twice as many seminars as female speakers, comprising the majority of invites (63.0% male). This overrepresentation of male seminar speakers is similar to previous studies including a multi-institution and multi-field study conducted in 2013 (69.0% male) and a single-department study also conducted over a five year period (62.0% male) (Hagan et al., 2020; Nittrouer et al., 2018). Unlike these previous studies, we included nonbinary gender identities in our analysis, and found that only 0.15% of speakers used nonbinary pronouns. Currently, the NSF and other agencies do not collect data on nonbinary gender identities; however, an estimation based on studies of the proportion of the LGBT population that identifies as nonbinary indicates that they comprise ~ 0.6% of the US population, suggesting an underrepresentation of nonbinary individuals in our data (Wilson & Meyer, 2021). Furthermore, we found that over the 5-year period studied the percentage of female and nonbinary scientists invited increased, mirroring a similar trend in the percentage of female and nonbinary faculty hosts. Accordingly, across nearly all departments studied, female and nonbinary faculty invited a larger fraction of female and nonbinary seminar speakers than their male faculty counterparts. These results complement other published findings that 1) departments with a female colloquium chair invited a higher proportion of female speakers and 2) female representation on conference speaker selection committees correlated with better gender parity among speakers (Casadevall & Handelsman, 2014; Ford et al., 2018; Kalejta & Palmenberg, 2017; Klein et al., 2017; Nittrouer et al., 2018).

Gender identity of host vs. gender identity of speaker

We found that gender identity of the host (whether faculty or trainee) was correlated with the gender identity of the invited speaker. Several factors could be underlying this phenomenon, and it certainly warrants further study. This result is somewhat similar to the finding that academic papers written by female authors cite a greater share of female-authored studies than papers written by male authors (Ferber, 1988). Ferber, the author of the study, suggested that this effect could be due to "gender-segregated networking"; it seems likely this could be a factor in seminar invitations as well. Stereotyping and implicit bias could also be at play: a recent study compared the strength of implicit science-is-male stereotypes

Hutto *et al. Discip Interdscip Sci Educ Res*   (2022) 4:21

Page 9 of 12

between male and female scientists (including social scientists, physicians, life scientists, physical scientists, and engineers) and found male scientists on average hold substantially stronger explicit and implicit science-is-male stereotypes than female scientists (Smyth & Nosek, 2015). Future studies should examine the contribution of these factors to the observed difference between male, female, and nonbinary faculty/student seminar invitations.

Trends in seminars over time

As predicted, we observed an increase over time in the fraction of female and nonbinary seminar speakers and faculty hosts. However, the magnitude of this difference (from approximately 20% to 50% for both metrics) is far higher than expected if driven by increased numbers of female/nonbinary scientists alone: the percentage of employed science doctorate holders from 2015 to 2019 only increased from 37.0% to 39.5% (National Center for Science and Engineering Statistics (NCSES), 2018, 2021). This observation, along with the observation that female/nonbinary invites from male faculty significantly increased over time, implies a cultural or behavioral shift among faculty and departments. We cannot be sure what is underlying this change, but recent increased scrutiny regarding gender representation among conference speakers, panels, and other academic practices may contribute to changing attitudes and acknowledgement of implicit biases (Casadevall, 2015; Casadevall & Handelsman, 2014; Ford et al., 2018; Goodman & Pepinsky, 2019; Harris et al., 2021; Kalejta & Palmenberg, 2017; J. L. Martin, 2014; Mehta et al., 2018a; Schroeder, et al., 2013a, 2013b).

Trainee seminar invitations

Our sample for trainee invitations was very small, and our conclusions from this data should be interpreted with this in mind. Nevertheless, we found that individual female trainees invited a greater share of female speakers when compared to all trainee invites, mirroring the phenomenon observed among faculty (no trainee invitations included nonbinary individuals). Trainees invited an increasingly larger number of speakers over the time period sampled, and a greater share of the speakers were female. This also mirrors the trend observed among faculty – and because the trend over time is likely culturally-driven rather than demographics-driven (see previous discussion), it is possible that there is cultural inheritance of biases/behavior in science departments.

Impacts of underrepresentation of female and nonbinary speakers in invited seminars through the lens of science identity

An important aspect to consider when evaluating representation within seminar speakers in science departments is the impact on trainees. While this is not the primary motivation for holding seminars, seminars do provide a clear demonstration of who is considered a scientist of import within the field. Our results demonstrate that students in nearly all departments studied are seeing fewer female and nonbinary seminar speakers than are found in their graduate student class. This is a critical finding as seeing role models with shared identities is an important factor in strengthening science identity among trainees, which in turn can affect retention in science and pursuit of scientific occupations (Stets et al., 2017; Stout et al., 2011). For underrepresented trainees (including gender identity and other held identities), not seeing people that share their identities held up as experts may contribute to a sense of not belonging and reinforce negative stereotypes about a particular group's lack of capability in that field. This narrative may contribute to other challenges to trainee success such as stereotype threat, wherein knowledge of negative stereotypes about their own group contributes to reduced academic performance (Murphy et al., 2007; Spencer et al., 2016; Steele & Aronson, 1995). Seminars also present students with potential access to outside scientific mentors and collaborators, which may be especially important in departments with minimal faculty diversity, as having female mentors strengthens scientific identity development among young women and increases their retention within STEM fields (Hernandez et al., 2017). Thus, striving for gender representation (and representation of other underrepresented groups) among invited speakers has salient impacts on the psychosocial development of trainees.

The scarcity of female and nonbinary seminar speakers may impact success and retention at the faculty level as well. As previously discussed, science identity can be affected by recognition of meaningful others as a scientist. An invitation to present at a seminar, especially for postdocs and early career scientists, can therefore strengthen science identity. While science identity at the faculty level has not been a major focus of research, data at the undergraduate, graduate, and postdoc level suggests that strengthened science identity is correlated with increased commitment to scientific careers (Chemers et al., 2011). However, it is worth noting that in Carlone and Johnson's original paper proposing their model of science identity, they documented the experiences of women of color that persisted in science despite the challenges in getting recognition from scientific others (Carlone & Johnson, 2007). Social supports seem to play a crucial role in strengthening science identity for scientists in historically underrepresented groups (Estrada et al., 2019). Aside from impacts on science identity, presentation at invited seminars is frequently considered in review for promotion; if women and nonbinary faculty

Hutto *et al. Discip Interdscip Sci Educ Res* (2022) 4:21

Page 10 of 12

members are invited to speak at fewer seminars, this may negatively impact their chances at tenure. Lack of access may also reduce the incidence of collaborations that arise from connections made across the country and around the world through invited seminars. While it is difficult to measure such effects, the more invited seminars one gives, the greater one's perceived importance and impact in the field. Unfortunately, because there is insufficient literature on the contribution of seminars to faculty success the full impact on female and nonbinary faculty is not known. Future research on the correlation between seminar invitations for junior faculty and tenure success would be useful.

Strategies for intervention

Despite an overall underrepresentation of female and nonbinary scientists in our sample, our results suggest that their representation among invitational department seminars is increasing in recent years at the institution studied. This trend is reflected by increasing numbers of female and nonbinary faculty hosts and male faculty inviting greater shares of non-male speakers over time. As such, both increasing representation of diverse identities among faculty hosts and changing behavior of faculty in majoritarian groups may represent promising avenues for achieving more diverse representation among speakers. The correlation between host and invitee gender identity supports calls from the literature for scientists to consider unconscious biases when inviting speakers, utilize resources such as DiversifyChemistry and Diversify-EEB to select speakers, and include more diverse voices on speaker selection committees (including trainees) (Casadevall, 2015; Hagan et al., 2020). Many additional resources exist to assist hosts in improving diversity in invited seminars, and can be used by seminar organizers and individual faculty hosts alike to improve representation among invited speakers (MacRae & Sang, 2018; J. L. Martin, 2014; Torgan, 2019).

Study limitations

An important limitation of this study is the usage of pronouns as a proxy for gender. For many reasons, a linguistic assumption of gender through pronoun usage does not accurately capture the gender identity of an individual (Cao & Daume III, 2020). In particular, we are unable to capture any information regarding whether individuals identify as cisgender or transgender. This information can only be accurately determined through surveys utilizing self-identification of gender identity. Unless the pronouns were taken from personal websites or are otherwise clearly self-identified, we cannot be certain that they accurately reflect a person's pronoun usage because a journalist or university colleague may assume someone's

pronouns for the purposes of writing an article or short blurb. Furthermore, for many reasons (including discrimination towards trans and nonbinary scientists) individuals may use pronouns in a professional capacity that mask their true gender identity. By using published pronouns as a proxy for gender identity, we are likely misidentifying some individuals. Gender is a complex and personal experience that may change over time, and by reducing that experience to pronouns, we fail to capture the breadth and diversity of gender identity. However, absent the ability to poll all individuals included in this study, we deemed this method of determining gender identity to be the most objective and best able to capture identities outside of the male/female binary. An additional limitation comes from binning nonbinary individuals with female individuals, thereby impeding our ability to examine differences between these populations. However, we deemed it necessary for this study to ensure anonymity for the exceptionally low number of assumed nonbinary individuals. While the experience and prevalence of discrimination within science may not be the same for women and nonbinary individuals, our choice to bin the two identities for this analysis reflects the underrepresentation of both populations within invited seminar speakers. A final critique of this study is that we did not examine the gender "pool" of faculty in each given field, which could significantly influence the number of female and nonbinary seminar speakers. However, a previous study adjusted for faculty pool size by gender and still observed an underrepresentation of female speakers (Nittrouer et al., 2018).

Our study examined patterns in invited speakers for seven departments over the course of 5 years. Several of the departments were fairly small (ranging from 19–68 faculty) and some had fairly few invited seminar speakers in each academic year (average number of seminars per year ranged from 8.8–34.2). Because of this small data set, our data may not be large enough to be conclusive and may not be generalizable to other institutions. However, based on the comparable outcomes between departments despite differences in size and scientific focus, we suspect that similar trends would be found at other sites.

Conclusions

This study examined a five-year period at an R1 institution and made the following findings: 1) Female and nonbinary scientists are underrepresented among invited seminar speakers, 2) Female and nonbinary faculty hosted a larger fraction of female and nonbinary speakers than their male faculty counterparts, 3) an increase in the number of female and nonbinary speakers over time coincided with an increasing number of female faculty serving as hosts and changes in male faculty invitations, and 4) trainee invitations largely

mirror trends in faculty invitations. These results build on and complement previous work showing that male scientists are overrepresented at departmental seminars (Hagan et al., 2020; Nittrouer et al., 2018) and that having female committee chairs increases female representation as speakers at academic conferences (Casadevall & Handelsman, 2014; Ford et al., 2018; Kalejta & Palmenberg, 2017; Klein et al., 2017; Nittrouer et al., 2018). Our finding of a relationship between individual faculty gender identity and the scientists that they host as departmental seminar speakers invites greater scrutiny of this practice, supports further investigation of the reasons underlying this relationship, and helps shape strategies that can be used to increase gender parity among seminars. Additionally, this work highlights the need for additional studies to better understand representation of nonbinary scientists, ideally with surveys that enable self-reporting of gender identity. Finally, future work should examine the relationship between faculty host and invited speaker gender identity at other institution types and also establish whether a similar relationship exists for other demographic variables (e.g., race & ethnicity).

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43031-022-00063-0.

Additional file 1: Table S1. Table S2. Yearly fraction of female/nonbinary seminar speakers invited, subdivided by department and host gender. **Figure S1.** Statistical details for the ordinary one-way ANOVA (A) followed by Tukey's multiple comparison test (B) performed in Figure1A. **Figure S2.** Statistical details for the simple linear regression analyses performed in Figure 2A (A) and Figure 2B (B). **Figure S3.** A) Individual distinct hosts were compiled for each department and the number of invites of each individual was totaled.

Declarations

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