Getting to Lake Wobegon

The Role of Departments in Diversifying Ph.D. Chemistry Graduates

Sandra L. Laursen and Timothy J. Weston

Ethnography & Evaluation Research, University of Colorado Boulder
Boulder, CO, 80309-0580, USA
Sandra.Laursen@colorado.edu

Abstract

The practices of graduate education in chemistry shape the quantity, quality and diversity of Ph.D. chemists throughout the workforce. Those who go on to academic careers influence the diversity of the professoriate that then shapes the next generation of chemists. This chapter reviews a comparative, quantitative analysis of trends in the productivity and diversity of chemistry Ph.D.s awarded by top US Ph.D.-granting departments in recent decades. Using time series data for individual graduate programs from a public database, departments are compared with each other and with national averages. The findings highlight departments that stand out—both positively and negatively—from their peers in educating a diverse group of Ph.D. chemists. Qualitative data suggests best practices for improving diversity in doctoral departments.

Introduction

In this chapter, we summarize work carried out together on the diversity of Ph.D. chemistry graduates, disaggregated at the departmental level. We think about this as "getting to Lake Wobegon," because the mythical Lake Wobegon, popularized in Garrison Keillor's stories, is a place where it is always pleasant: where the women are strong, the men are good-looking, and the children are all above average. Realistically, of course, departments can't all be above average when it comes to their graduates' diversity—but like the residents of Lake Wobegon, people in many departments think they are above average, when the data in fact show a less optimistic picture. In this chapter we consider what the data do tell us and discuss ways we might improve our record, locally and as a discipline, with respect to graduate student diversity.

I (Laursen) am originally a chemist, although I haven't been working in chemistry for the last several years. Our research team studies science education and career paths in an independent research unit at the University of Colorado Boulder. The analysis discussed here was a part of a larger study funded by the National Science Foundation (NSF) about the professional preparation of Ph.D. chemists. We were interested in how chemistry departments were responding to calls, over the last two decades or more, for reform of graduate education, especially in preparing students for a wider range of 21st century careers. Our team was interested in how departments were or were not responding to these calls, and to the issues they identified—and in what students were or were not experiencing for career preparation. I summarize here just one part of that work.[1]

Preparing Ph.D.s in Chemistry

Our study focused on chemistry because chemists seem to be distinctive in terms of their career, interests and ambitions, compared to other fields. Sauermann and Roach collected data on the career interests of Ph.D. students in life sciences, chemistry and physics, and how these changed from early to late stages of graduate school.[2] Chemistry Ph.D. students' levels of interest in jobs within industry and government were higher than those of students in other fields, and those interests increased more steeply during their graduate school years, particularly when compared to their interest in academic jobs, which declined. The trends were rather less pronounced in physics and the life sciences.

Thus our team was particularly interested in chemistry as a field where students need and should have good information about their career options other than academe. Chemistry graduate students know a fair amount about academe because they watch their faculty; they see what faculty work is like, and what faculty lives are like. But their opportunities to learn about industry or teaching in other contexts, working in government or in small startup firms, are fewer. Also, of course, like all the sciences, employment in chemistry has become less secure, and unemployment rates have increased, according to data routinely collected by the American Chemical Society.

Our study had two components. One component, called the Mapping Study, was a broad look across the landscape. For this study, we did some quantitative data collection, which is described further below.[1] We also interviewed people who were department chairs or directors of graduate education in chemistry departments about these changes they had made or were thinking about making in their preparation of students, especially with respect to career development.[3]

Our research team also visited three departments where we conducted in-depth case studies, interviewing large numbers of students, faculty, and staff who worked with graduate students, such as in TA preparation or analytical labs. We spoke with students about their career interests, and to students, faculty and staff about how students identified their career interests and prepared to search for and hold those careers after graduation.[4,5]

Diversity among Ph.D. Graduates in Chemistry

The focus of this chapter is one part of our Mapping Study, examining who is graduating from chemistry departments. We heard a good deal about diversity concerns when we talked with chairs and directors of graduate education. This was an issue on leaders' minds, one that was coming up in terms of changing demographics and changing needs within the department around those.

Nationally, in the U.S., about 2400 Ph.Ds. in chemistry are awarded each year.[6] This number has been fairly stable over the last couple of decades. That accounts for about 60 percent of the Ph.Ds. in physical science, nationwide, or about 7 percent of all Ph.Ds. in science and engineering, as NSF defines it, which includes the social sciences.

About five percent of chemistry Ph.D. degrees go to people from underrepresented minority groups. In labeling the text and figures, we use a somewhat unfortunate acronym, URM. This term 'underrepresented' always refers to groups, which may be underrepresented relative to their presence in the population at large. As individuals, people are not URMs: everyone is represented exactly once. For this study the URM category includes African American, Native American, and Hispanic or Latino/a graduates, summing the data for these groups that are available in IPEDS. These groups are traditionally and persistently underrepresented in the sciences.

About 34 percent of chemistry Ph.D. degrees go to women. Here our language refers to the socially constructed category of gender. The categories are women and men, not female and male, which refer to biological sex. In this chapter we focus on diversity with respect to gender, race and ethnicity.

Study Methods

In this quantitative study, the data are taken from a dataset called IPEDS, the Integrated Postsecondary Education Data System, which is available from the U.S. Department of Education.[7] At each institution, the registrar or institutional research office will gather these data for all departments, tallying the degrees awarded across the institution. Participating in this data collection is required if the institution takes any federal aid money, so the data tend to be quite complete.

In her presentation, Mia Ong pointed out that she didn't have numbers for certain categories of people, because the NSF doesn't publish data broken out by certain race and ethnicity categories, if the numbers are too small. The principle behind that is publishing small numbers can identify people as individuals. Suppose the data show that there are five Native American chemists—that small number means it is easy to figure out whether you know some of them. NSF does this in an attempt to protect privacy, but IPEDS doesn't protect privacy in that same way. It is possible to acquire all the data individually resolved by department: for example, I can look up CU Boulder's chemistry degrees to learn how many graduated in each of these categories, and I can go backwards in time to build a time series. This data set is disaggregated back to 1987 by gender, and back to 1995 by race, ethnicity, and citizenship.

This makes for somewhat tedious data collection, but it is advantageous because it is all public data. We joined the data together to build a picture of the change over time by departments. As a trained chemist, I thought about this as a kinetics problem: What are the rates of change in these departments over time?

Our study used a set of 50 top-ranked departments, compiled (at that time) by David Fraley from several different national rankings.[8] The results would not be very different if one took a different set. The National Research Council rankings don't give a numerical ranking any more; they give a range, so they were not useful for our purposes. What is important is that the 50 departments in our data set account for about 60 percent of all Ph.Ds. in chemistry, and the trends seen in that set of 50 are very parallel to the national trends.

Practically speaking, the departments not included tend to be the smaller departments. Once the number of graduates drops below about 10 Ph.Ds. per year, the data start to become quite noisy, as the numbers of graduates go up and down every year, depending on when students finish. Including these smaller programs adds more noise than signal to the dataset.

The variables we studied for each institution include total Ph.Ds. awarded, Ph.Ds. by gender and by race, and Ph.D.s for citizens and non-residents. We also used some other public data such as the proportions of faculty for each institution by gender and race, drawing on the Nelson Diversity Surveys.[9,10]

The data were analyzed with hierarchical linear modeling (HLM), which treats the data as nested: each year of data is nested within each institution. HLM properly accounts for the variation among institutions but also the non-random relationships between one year of data to the next for any given institution. Full details of our data sets and analysis are provided elsewhere and are not repeated here.[1]

This analysis of time-series data, disaggregated by department, enabled us to ask questions such as, How is the representation of women changing over time? Is the diversity of graduates changing in the same ways for departments that graduate more or fewer Ph.Ds.? We were most interested in the difference in rates of change, or trends over time.

Trends in Gender Diversity

Figure 1 compares the NSF data, aggregated across all the chemistry departments that NSF tracks, and shows that our 50-school data set tracks that very well. In other words, the set of schools we studied is representative of the national set. It is also clear that, over time, the proportion of women earning Ph.Ds. in chemistry has increased.

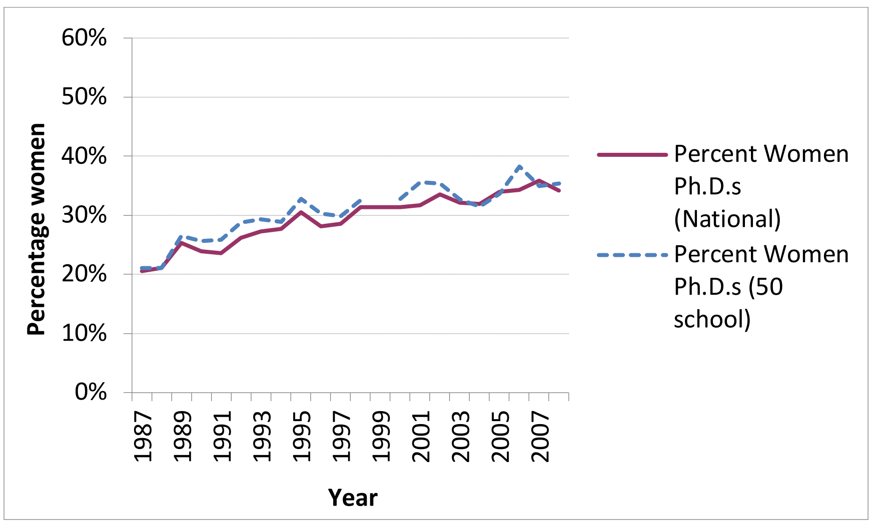

Figure 1: Women's representation is increasing, nationwide and in our study. Adapted with permission from reference 1. Copyright 2014 American Chemical Society

What is important in this study is that we have disaggregated these averages. Instead of just looking at the national trend, we have examined the trend for each individual department for the years 1987-2009. Table 1 shows the mean percentage of women for the last five years of this period (2005-09), and the average growth rate over the entire time from the hierarchical linear models, for a few departments. Those are two different things: chemists might think about them as concentration and change in concentration. For comparison, the mean for all 50 schools was 36% women (2005-09), and 14% average growth (1987-2009). The results for all the schools in our study can be found in Table 4 of the original paper by Laursen and Weston.[1] The table shows substantial variation from department to department. Which departments were outliers in both positive and negative directions, and why?

Table 1: Women's representation does not increase evenly in institutions

Top 8	*% women (mean 2005-09)*	*growth in % women, '87-'09*	*Bottom 8*	*% women (mean 2005-09)*	*growth in % women, '87-'09*
Louisiana State	49%	23%	Harvard	20%	7%
U. Washington	47%	30%	Chicago	24%	5%
Michigan State	47%	29%	Columbia	27%	9%
Florida	45%	27%	Colorado State	28%	6%
Emory	44%	10%	Ohio State	28%	12%
Georgia Tech	41%	20%	Washington U. (St. Louis)	28%	-3%
Purdue	40%	15%	UC Santa Barbara	30%	3%
UNC Chapel Hill	40%	11%	Iowa State	30%	8%

The wide range among departments suggests that women in chemistry don't experience the same environment in every place. The department matters—it matters a lot. The success rate of women in graduating with a Ph.D. does depend on the local environment. This way of thinking treats the department as a proxy for the local climate, the local educational system that people go through. We are interested in the variation of that and what it might tell us about success.

Although the national average for women is about 36 percent, during the last period of time that our data cover, clearly some departments exceed that by a long way, having nearly half women. Within this latter time, the proportion of women getting bachelor's degrees in chemistry has been about half. So the pool of people who might attend graduate school has more women in it: overall, the representation of women in departments *ought* to be going up across the board. So it is puzzling that there are also departments where the percentages of women have not changed much and are not going up. In some cases, the trendline is pretty flat. This is a signal that there is an issue: something about those settings is not conducive for women completing degrees.

It's important to acknowledge that the data that are available address completion of Ph.Ds.; we know very little about admissions or retention. From these data, we can't determine whether fewer women are coming into those less gender-balanced departments, or whether women are coming in but not finishing. Nationally, there are not strong data on admissions and entry into graduate programs, so we can't identify whethere the bottleneck lies in application, admission, or retention. But that is something that department chairs could investigate to diagnose the situation in their own departments.

The national average in percentage of women among chemistry Ph.D.s is climbing fairly steadily. It parallels the growth in bachelor's degrees to women, although it lags that by more years than one might expect. Some departments really stand out in both directions, as doing a better job of helping women succeed or as not doing such a good job. The growth in Ph.Ds. tracks the growth in bachelor's and master's: demographics are helping doctoral programs here. More women are coming into the field, so they should be better represented in graduate applicant pools and have more opportunity to enter chemistry doctoral programs and succeed there.

In addition to these trends, our study looked at the correlation of these growth rates with other factors, where we could find appropriate data. Our initial ambition was to consider the business case for diversity, to examine the relationship of quality to diversity in chemistry departments, but we didn't have enough indicators of "quality." We did consider a few measures, including size and faculty composition. We found that, in general, bigger departments granted a lower proportion of degrees to women. Smaller departments tended to be more conducive to women's completion. But *growth* in the number of Ph.D. graduates was correlated positively with growth in women graduates. In other words, programs that were growing were also those that were recruiting and graduating women, and that fact alone may explain why they were growing.

We found no statistical linkage between the proportion of women getting chemistry degrees and the proportion of women faculty. This was a surprise because previous work has shown that there is a link between the number of undergraduate women getting degrees in science and the faculty composition.[11] We didn't see it for graduate students, and it may have to do with the simple fact that there wasn't much variation in the proportion of women faculty. In other words, very few of these departments had a critical mass of women faculty, so there just wasn't enough range to detect any statistical relationship. We would have expected that there would be some relationship, but we didn't find it.

From the literature, and from some of the interview data with chairs,[3] we know that some factors did matter, including the arrays of mentoring programs and student success programs in the department, and women's perception of a collegial environment. Interdisciplinary work turns out to be often attractive to women, too, and departments that had emphasized interdisciplinary work had noticed a rise in women.[3]

Trends in Racial, Ethnic, and Citizenship Diversity

The data on Ph.D. graduates from underrepresented groups are less encouraging. The numbers of students graduating are much smaller and haven't changed very much over time, as seen in Figure 2. The IPEDS data set also goes back less far in time; previous to 1995 it wasn't disaggregated by race, ethnicity, or citizenship. Nonetheless, the proportion of URM Ph.D. graduates has been stubbornly sitting near five percent for a while. So numbers for minority doctorates are not getting help from the demographics of the undergraduates. For URM students, the field is not seeing the concomitant growth due to undergraduate bachelor degrees in chemistry that is the case for women; the situation looks different.

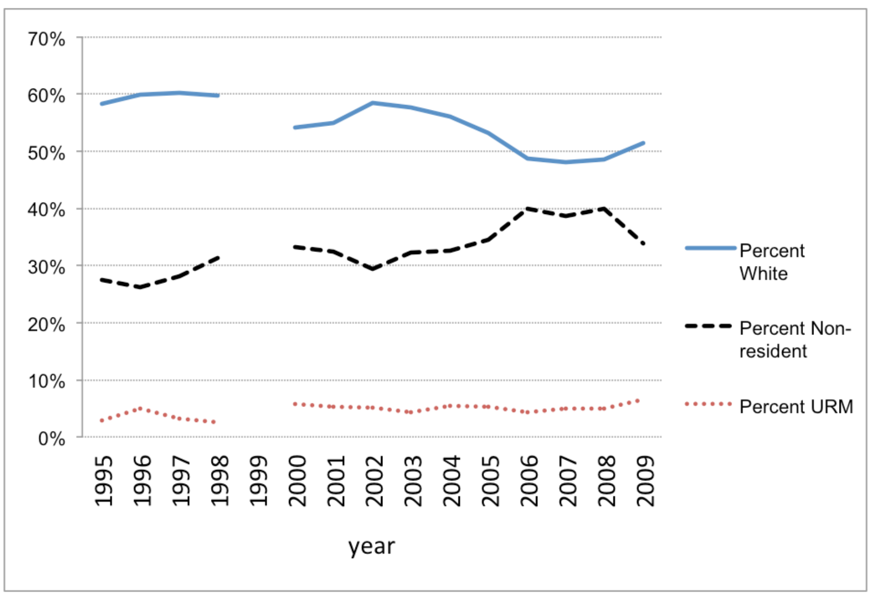

Figure 2: Proportions of underrepresented students remain small. Adapted with permission from reference 1. Copyright 2014 American Chemical Society

The data do show that student bodies over time are becoming more diverse over this time period in other ways. Again the IPEDS data for our 50 schools track the national trends (Figure 2): the proportion of white students has dropped nationally, and the proportion of students from other countries—labeled "non-residents" in the IPEDS data—is up. The proportion of minority students is not changing terribly much; there is a positive trend, but not a large one.

Upon considering other factors, we found that the larger departments tended to be less diverse by race and ethnicity, as was the case for gender. However, we find that the connection of racial and ethnic diversity to faculty composition is stronger for URM students. That is, a more diverse faculty is associated with a more diverse student body of graduates. But, as in the case of women, what was most interesting to us was which particular departments were succeeding in recruiting and retaining to graduation Ph.D. students from minority groups.

Table 2: URM representation does not increase evenly across institutions

Top 8	*% URM (mean 2005-09)*	*growth in % URM, '95-'09*	*Bottom 8*	*% URM (mean 2005-09)*	*growth in % URM, '95-'09*
Louisiana State	20%	11%	Wisconsin	0%	-3%
Purdue	17%	17%	Illinois	0%	-2%
UC San Diego	11%	7%	Columbia	0%	-2%
UCLA	10%	9%	U. Southern California	0%	-1%
Florida State	9%	9%	Penn	1%	-3%
UC Irvine	9%	8%	Chicago	1%	-2%
Harvard	9%	6%	Minnesota	1%	-1%
UC Santa Barbara	9%	2%	Pittsburgh	1%	-1%

In this case, the national averages are poor, so the standout departments are beating the averages by quite a lot. Table 2 highlights the programs that have had good success in graduating minority student Ph.D.s in chemistry, and other schools whose records are flat or declining in the proportion of underrepresented minority students among their graduates. The data are presented the same way as in Table 1, showing the five-year mean for the last five years of the data set (2005-09), and the growth over the full period of the data set (1995-2009). Data for all 50 schools we studied are available in Table 8 in the original paper.[1]

The important take-away message from these analyses is that the national averages hide a lot of variation. Yet that variation is quite interesting because it tells us something important about what is going on. Some of that variation will be random, but some of it is also due to local conditions. Chemistry department chairs and faculty leaders are empowered to investigate these trends for themselves, and to find out what is working and what is not working for graduate students in their own departments. The literature is a guide to the kinds of issues to consider, but the factors that attract or deter, hinder or retain diverse students will be a unique mix at each institution. Local leaders can do the inquiry—the data gathering and the listening—that are needed to get to the root of these issues in their own departments.

What Practices Foster Diversity in Chemistry Ph.D. Programs?

The standout schools that are beating the averages are particularly interesting examples to examine, to see what they have done to make this trend a reality. We couldn't detect the sigmoidal shape that would tell us the moment when people started to work on this and make a difference—too many other variables affect the data, and there is a time delay between when action is taken and when it appears in the graduation data—but we can still see the eventual evidence of success and can still learn from the experiences of these programs.

Our interview data helped to explain some of these trends.[3] First, diversity varies widely among departments, so what people mean when they talk about diversity also varies locally. What kind of diversity you have is variable, and appropriately so.

We found that the departments whose data showed that they had been more successful were aware of it. They could quote their numbers and could tell us what they had done to work on them. In contrast, other people said to us, 'Oh, we are about average.' And when we looked at their numbers, they were actually rather below average. So the people who were conscious of their department's status with respect to diversity were more accurate in their estimation of how they stood relative to others. If you really do live in Lake Wobegon, you know it.

Knowing and tracking the data seem to be important. A few departments that were successful, including Purdue and Louisiana State (Table 2), were very deliberate about preparing a diversity plan. Whether that occurred as a top-down requirement from the provost, or as an initiative coming up from the bottom, seemed to matter less than that people had a plan and took it seriously. These plans included what was going to happen and who was accountable for it: naming names or roles to take specific actions among the staff or among the students, to track the data, and so on. Purdue's chemistry department diversity plan is one that is worth examining as an example, as it is very detailed, impressive in the amount of detail.

Also from the interview data, we learned that the departments that had been successful in diversifying their student bodies were looking at both recruitment and retention. They had done something specific to recruit more diverse students, and then also made sure that these students would succeed when they came. Some of these were examples of the counter-spaces that Mia Ong described, and some of the strategies like those Malika Jeffries-EL discussed for helping people find each other and connect as women or as Black students.

Other programs that fostered diversity were ones that would benefit all students. For example, having a student handbook turned out to help all students—being clear about expectations, timelines, whom students can go to with various problems or questions. But these approaches particularly help students who might be solo status or near it, because those students often don't have the informal, interpersonal networks of people who can tell them that important information about how things work. And so such strategies can disproportionately benefit students from underrepresented groups by just providing clear information, and by establishing checkmarks and benchmarks: 'You should have done this by the end of year two; you should have done this by the end of year three.' At the same time, laying those things out, making clear what path was expected, and what to do if you weren't making those benchmarks, was helpful to all students.

Our interviews also revealed that departments that had positive faculty climates also had positive graduate climates. These climates were interlinked. For example, institutions that had campus NSF ADVANCE initiatives[12] that were trying to improve gender equity across campus in the STEM fields tended to feel a positive effect from that. As faculty felt more positive, as graduate students observed their faculty leading whole lives, being full people, bringing small children to the department after school, or whatever they noticed, the students too had more positive views of the department climate and more positive views of their possible futures in chemistry—a positive spin-off. And in fact, these tools for retaining faculty turn out to also retain students. A good climate is good for everybody.

Finally, these departments had observed that, when they sought to build a critical mass of women or of students from underrepresented minority groups, they had to work hard for a while—but then the situation started to take care of itself. Departments had to keep some efforts in place, and keep tabs on their progress, but the students became their best spokespeople. The increasingly diverse graduate students recruited more students, who were also diverse. And so this becomes the way things are done. The students will speak on behalf of those efforts. The departments who had succeeded noticed this very good side effect: It isn't hard work forever, they told us.

Implications for Chemistry Departments

As other chapters in this volume point out, the individual stories tell us why people stay or go from science. They tell us what is hard about doing science and being a scientist, for people who look around the room and don't see many people like themselves. Statistics like those shared here lump all those stories together, and do not explain any one individual person's story. But by unpacking the statistics from the national averages down to the department level, we offer some evidence that local factors do matter. The wide differences seen in the data are probably not accidental. There is certainly random variation in the middle, but at the far ends, these data offer lessons about how to make departments happier places, where everybody does lots of exciting science and thrives.

We share these findings not to shame anybody, although we are not averse to a little positive peer pressure if it inspires people to take action. We hope department leaders will consult the detailed data in the original paper by Laursen and Weston in the *Journal of Chemical Education*.[1] This paper includes a list of resources and references, and a few of interest to leaders are highlighted here.

- The chemistry department's diversity plan at Purdue University
- Material on recruiting for diversity from the University of Michigan's graduate school
- Materials on reruiting for diversity from the University of Washington
- Data and practical ideas in the Woodrow Wilson Foundation's report on *Diversity and the Ph.D.*[13]

A final resource is based on work by Laursen with Ann Austin from Michigan State, examining NSF ADVANCE programs on gender equity and representation at the institutional level. These programs are not focused on STEM graduate students but on faculty. Our practical resource, the StratEGIC Toolkit, includes many ideas for interventions relevant to equity, expressed in user-friendly forms. Some of these ideas would have to be implemented at the institutional level, such as policy changes, but some are interventions that department leaders can change or initiate locally.[14] What is important in both situations is using data to diagnose the local situation, and then taking responsibility to improve it.

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Appendix

Following this presentation at the National Diversity Equity Workshop, the following questions and answers were transcribed:

Q: As department chairs, we are judged on the quality of our program, not on diversity. Does the diversity of graduate programs relate in any way to the quality or ranking of programs?

A: It is a good question. I would love to have found that correlation. I was looking for it, but I didn't find the data that would let me explore it. But certainly there are data that show that diverse work groups are more productive and creative, come up with more ideas. That will be true for scientific groups too, not just business units.

As the ADVANCE institutions have found, the argument that diversity matters for social justice—to provide equal opportunity—speaks to some people. But it doesn't speak to everyone, so you can't rely on that argument holding sway. A stronger argument for some people is about excellence: if you don't have a group of entering students that looks like the nation, or at least look like the graduating bachelor's degree chemists, you are not plumbing all the talent—because there is no evidence that talent is localized to any particular set of people. Opportunity certainly is localized, but talent is not. And so, if you are not seeing those people come in, you are missing some of the best and the brightest. And I think that is the best argument I have about quality and diversity.

I wish we had better quantitative data to support that, especially for graduate education. There are reasons it is hard to fish out; the numbers do vary a lot. Maybe over time, we will have that. I would like to come back to these data in ten or fifteen years and see if we can see any greater trends.

Q: How might we take diversity into account in admissions? Should we be using different types of application data, such as interviews, rather than data such as grade-point averages and GRE scores, for which we know some groups are more advantaged?

A: There are some good examples of how these traditional admissions data are biased, and there is evidence to point to the fact that there are other criteria that matter. As academic chemistry faculty, you know from working with graduate students in your labs that the qualities that enable students to succeed in research are not necessarily the same qualities that enable them to succeed in classes, the high GPAs, the test scores and so on. Perseverance and curiosity and creativity and things like that—those are harder to measure but they matter a lot. And that is why I think the interview kinds of measures are useful. Essays may also be useful in some respects. So, I think there is promise in looking at such measures, and letting go a little bit of our beliefs about GREs.

We do certainly know that students need to be prepared in terms of writing and quantitative skills, but probably the issue of who is 'prepared' starts earlier than we think. This is not just about students' college experience. So I think there is promise for increasing diversity in looking at graduate admissions criteria.

What you have been learning from other speakers about implicit bias, that absolutely applies to graduate admissions. We read letters differently, we write letters differently for women students and men students. So anything you learn there absolutely applies to graduate admissions. It would be very interesting to think about doing more blinding of applications, to address implicit bias. I don't know if people have tried that.

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