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INCLUSIVE PATHWAYS TO INVENTION: RACIAL AND ETHNIC DIVERSITY AMONG COLLEGIATE STUDENT INVENTORS IN A NATIONAL PRIZE COMPETITION

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We present novel evidence from over 2,000 student inventors from colleges and universities across the United States who applied to a prestigious national prize. These unique data provide us with self-reported information about gender, race, and ethnicity for students earlier on the "pathway to invention" — young people who have already shown evidence of their inventiveness and are among those likely to be future patent holders. First, we show that 14% of prize applicants are from under-represented minority (URM) groups, which is a smaller gap than estimates of the racial/ethnic gap in patenting. We find striking differences in the focus of the inventions being created by URM inventors, particularly at the intersection of gender and race: URM men are much more likely than all other groups to work on consumer-oriented inventions and less likely to work on health care inventions. URM women are similar to non-URM students in being most likely to work on health care inventions. Differences by field of study show that URM men are more likely than other groups to come from business, and URM women are more likely to come from biological sciences. Finally, we show that slightly more URM applicants come from public research universities. A fruitful area for future research is examining the ways different types of universities support the development of URM students as inventors and contribute to URM students' continuation on the pathway to invention.

Key words: Innovation; Inventors; Patents; Race; Diversity; Universities

INTRODUCTION

Efforts to examine issues related to gender and racial diversity among inventors in the United States are challenging, as demographic information is not collected in the United States Patent and Trademark Office's patent application process. Researchers have developed novel approaches to identify female inventors and inventors from under-represented racial and ethnic groups by comparing applicants' names to those in other data sets that also contain information for gender and race/ethnicity. This research has shed light on the stark and persistent gender, racial, and ethnic gaps among inventors (e.g., 1,2).

Researchers' ability to understand who obtains patents and what they invent has informed our understanding of why it is in the public interest to enable more people from diverse backgrounds to invent and successfully navigate the patent process. Scholars have shown that the lack of diversity among inventors impacts what is — and what is not — invented. In a study of biomedical patents, Koning, Samila, and Ferguson (3) found that women were more likely than men to have patents focusing on the health needs of women in particular. Inventors are shown to generally be more likely to create products that are relevant for and purchased by customers similar to them (4). Other studies have suggested that greater diversity in innovation activities through greater participation of women and under-represented groups could increase economic growth (5-8).

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In recent decades, women and under-represented minorities (URM) have been increasingly represented among degree holders in science, technology, engineering, and mathematics (STEM) fields, but there has not been a commensurate increase in representation among patent holders (9) or STEM occupations (10). Why have these racial and ethnic gaps persisted among inventors, and what are their implications for innovation?

This paper presents novel evidence from an ongoing study of over 2,000 student inventors from colleges and universities across the United States who applied for a prestigious national prize for promising collegiate student inventors. These unique data provide us with self-reported information about gender, race, and ethnicity for applicants. We recognize that this sample of students is not representative of all student inventors nationally but is rather a group who learned about the opportunity and chose to apply to this particular prize program, so we cannot generalize to all students or all student inventors. Yet, understanding diversity among this group offers insights into diversity earlier on the "pathway to invention." Applicants have already shown evidence of their inventiveness by having a tested prototype, and thus are among those who may become future patent holders. The literature on diversity in STEM fields and innovative activities has pointed more broadly to the importance of discovering new ways of attracting and retaining women and URM in STEM fields, which our unique data allow us to examine (see, e.g., 11,12).

Our analysis focuses on the types of inventions URM student inventors are working on and the extent to which they differ from the inventions of non-URM students, where URM are students who reported their race/ethnicity as African American or Black, Hispanic or Latino, or American Indian or Alaska Native. Applicants were required to submit evidence of their work in developing technological solutions to problems they identified in one of four prize category areas: health care, transportation or mobility, food/water or agriculture, or consumer devices or products. We are able to draw on information about the distribution of applicants by race and gender across these prize categories to understand differences in the focus of the inventions. We also examine applicants' fields of study and types of universities (public/private, research or non-research) to inform efforts to locate and bring added support to URM students so that they are more likely to continue on the pathway to invention.

These unique data allow us to examine the following research questions among promising student inventors: (a) Are there differences in application rates across the four prize categories among women and men who are URM versus non-URM? (b) Are there differences in the fields of study? How do the applicants' majors compare to enrollments in those majors at colleges and universities across the United States? (c) Are there differences in the colleges/universities attended by applicants?

First, we show that 14% of applicants to the prize were URM. The proportion of URM applicants exceeds what might be expected given that estimates suggest that only 5% of U.S. patent holders (regardless of gender) are a race other than Asian or White, an occurrence referred to as the racial/ethnic gap in patenting (5). We also find a larger racial/ethnic gap among graduate students than undergraduates, as 15% of the undergraduate applicants are URM compared with only 11% of the graduate applicants. Second, we find striking differences in the focus of the inventions being created by URM inventors, particularly at the intersection of gender and race: URM men are much more likely than all other groups to work on consumer-oriented inventions and less likely to work on health care inventions. We also find that URM women are similar to non-URM students in being most likely to work on health inventions. Accounting for the applicants' major field of study helps explain the difference in consumer-oriented inventions but does not explain the difference for health care inventions.

These differences are further reflected in the applicants' fields of study. Overall, most applicants come from engineering, and this is consistent with the fact that 60% of patents granted to U.S. inventors in 2018 related to electrical and mechanical engineering (13). However, we find that URM applicants are less likely than non-URM applicants to come from engineering fields. However, we find again that results vary by race and gender, with URM men more likely than the other groups to major in a business field rather than a STEM field. Female URM applicants, meanwhile, are the most likely to be studying in a biological sciences field, pointing to an important reason for the high representation of URM women applying to the health care prize category.

Next, we focus on what types of universities the applicants are coming from. We find that public research universities appear to be playing an important role as a source of URM applicants to the prize; URM applicants are less likely to come from research universities overall (R1 or R2 in the Carnegie Classification) than non-URM applicants but are slightly more likely than non-URM applicants to come from public research universities. We show that, overall, 53% of the URM applicants are coming from public institutions versus 48% of non-URM applicants. Yet, when looking at who went on to win a prize, we see that only two of the seven URM applicants who are winners (7% of all winners are URM) attended a public college/university. We also find that URM men are the least likely to come from private research universities and non-URM women are the most likely. Additionally, URM men are slightly more likely to come from non-research universities and are more likely to be pursuing a business major.

These findings make several contributions to the literature on diversity in innovation. First, few existing studies of patent holders are able to explore the intersectionality between gender and race/ethnicity, which our data allow us to do. Second, we are able to observe inventive activities for individuals earlier on the pathway to invention. Scholars have pointed to the need for a broader measure of innovative activities beyond patenting since patenting is a low-probability event and is a milestone that may only be achieved after many years of work. Student inventors in our sample have already shown evidence of their inventiveness by having a tested prototype, holding a patent or being likely to in the future, and contributing to other innovative activities.

Our results indicate the need for further research in numerous areas that can inform public policies related to invention, particularly regarding the focus of inventions by student inventors. First, our analysis underscores the importance of looking at the intersectionality of gender and race as it relates to patenting activity and the development of inventors. Collecting this information on patents is an important policy consideration. Second, while we looked at broad categories of inventions and found that URM men tended to work on consumer goods, more research into the specific types of consumer goods will be important to better understand these differences. Our results show that more URM applicants are coming from public institutions, and more non-URM women are coming from private institutions. Further research can examine the extent to which public institutions are fostering student inventors from diverse racial/ethnic backgrounds and can determine whether private institutions are having particular success in supporting non-URM women. This line of research would contribute to the studies showing the important role universities can play as engines of social mobility (14,15) and would inform policy efforts to locate and bring added support to URM students so that they are more likely to continue on the pathway to invention. Finally, more analysis on the role of collaborations and inventor teams at the undergraduate level can help shed light on the extent to which team-based approaches to invention are helping to engage inventors from more diverse backgrounds.

Our paper is outlined as follows: Section 2 discusses the history of the Lemelson-MIT (LMIT) Student Prize program, the applicant data, and methodology. Section 3 describes our results by race and gender. Section 4 concludes and discusses fruitful areas for future research.

DATA & METHODS

The LMIT Student Prize honored a small number of promising student inventors in the United States between 2014 and 2021 (eight years of national awards). The Student Prize was open to teams of undergraduate students and to individual graduate students who had technology-based inventions in categories that represent significant sectors of the economy (Cure it! for health care, Move it! for transportation or mobility, Eat it! for food/water or agriculture, and Use it! for consumer devices or products).

All applicants had to be full-time, degree-seeking students at any U.S. college or university. Undergraduates were required to apply as a team of two to five students with a tested prototype of one invention that fit into one of the four prize categories. Teams could be from multiple institutions and could have a mix of graduates and undergraduates provided there was a majority of undergraduates on the team. Graduate students had to apply individually with at least two inventions with tested prototypes, and only the primary invention had to fit into one of the four prize categories.

The prize application process consisted of multiple rounds. Applicants submitted an initial application that had minimal requirements to one of the four prize categories. The 2014 prize cycle only consisted of two prize categories (Cure it! and Use it!); the 2015 to 2021 prize cycles had all four prize categories. All eligible applicants were automatically advanced to the category application round, where they had to submit a faculty letter of recommendation and detailed written responses, including a description of inventiveness, potential for commercialization or adoption, systems and design thinking, and youth mentoring experience. Category applications were reviewed by four screening committees (one per category) with expertise in the field area pertaining to the prize category. Screening committee members had to be affiliated with MIT [Massachusetts Institute of Technology] in some capacity, such as faculty, staff, alumni, and past Student Prize winners. Each screening committee selected up to six finalists (graduate students and undergraduate teams combined) per category to advance to the Finalist round. Finalists had to submit two additional letters of recommendation and a 2-minute video about their invention (primary invention for graduate applicants). All finalists were reviewed by a separate group of judges called the National Jury, comprising experts from a variety of disciplines to represent the four categories. The National Jury selected up to eight winners per year (typically one graduate and one undergraduate team

Table 1. Example Descriptions of Winning Inventions by Category (2017-2021 Prize Winners)

Prize Category	Examples of Winning Inventions
Cure it! (health care)	Biomimetic eardrum grafts to repair damage; early screening tests for prenatal care; health care advances for amputees that restore a sense of touch and better mobility; a reusable, low-cost, contamination-free breast biopsy device; and a cervical cancer diagnosis device.
Eat it! (food/water/agriculture)	A grain bin safety and management robot to help farmers; a variable volute water pump for better energy efficiency; real-time health analysis device for pig farmers; charged polymers for sticky agricultural sprays; and electrochemical water purification technology.
Move it! (transportation/mobility)	Autonomous wheelchair technology; a wireless device that opens disabled-accessible doors; a system to capture clear images through dense fog for augmented driving; and a small, mid-air deployable, folding electric drone.
Use it! (consumer devices and products)	Recycling systems to transform PET plastic waste; biodegradable plastic; chemical reactors for sustainable chemical processes; and a daily-wear nasal breathing aid.

per category). Examples of previous winners in each category are provided in Table 1.

LMIT worked to identify a broad and diverse pool of potential applicants and conducted an active marketing campaign by advertising in student newspapers and via social media. They contacted an average of 1,200 promising student candidates each year to provide more information about the prize in advance of the application deadline. Each year, LMIT compiled a targeted list of schools to find prospective prize applicants. For each school researched, LMIT compiled lists for direct outreach to encourage applications, including prospective students and faculty/staff/administrators who might refer students. Starting with the 2017 prize cycle, the list of schools to research consisted of the top 100 to 120 schools from the annual *U.S. News* Best Graduate Engineering Schools (with a doctorate degree) rankings. They also researched the top 30 to 40 schools on the *U.S. News* Best Undergraduate Engineering Schools (no doctorate) list.

Approximately 50 more schools not appearing in the *U.S. News* engineering school rankings were added to the school lists beginning with the 2018 prize cycle. These additional schools were compiled from miscellaneous school rankings that aligned with LMIT's desire to both increase the overall diversity in the applicant pool (more women and URM applicants) and increase the number of applications submitted in certain categories (particularly Eat it! and Move it!). Schools added to the research list consisted of Historically Black Colleges and Universities, top female engineering schools, and schools with top industrial design, agriculture, and business programs. LMIT continued to use these lists and expanded to slightly more schools using the same protocols for the 2019 prize cycle.

Beginning with the 2020 prize cycle through the 2021 prize cycle, they further expanded the list of targeted schools to include over 200 top community colleges. LMIT staff indicated that it was often impossible to find contact information for direct outreach to community college students, so most outreach to community colleges was sent to faculty and administrators for their distribution to students.

This paper reports the analysis of archival data from 2014 to 2021, the years during which the program was open to students at all universities in the

Table 2. Characteristics of Sample Compared to Sample without Race/Ethnicity

	Race/Ethnicity Self-Reported	Race/Ethnicity Not Self-Reported	Difference
Female	0.289	0.201	0.089***
Undergrad	0.717	0.772	-0.056*
STEM Major	0.820	0.836	-0.017
Engineering	0.570	0.544	0.026
Computer and Information Sciences	0.125	0.150	-0.024
Biological and Biomedical Sciences	0.064	0.073	-0.009
Public	0.487	0.419	0.067**
Research Univ. (R1/R2)	0.876	0.862	0.013
Prize Category			
Cure it! (Health)	0.471	0.444	0.028
Eat it! (Food)	0.147	0.147	0.000
Move it! (Transport)	0.078	0.127	-0.049***
Use it! (Consumer)	0.304	0.283	0.021
Observations	1671	501	

Note: 1) The sample used in the analysis (N = 1,671) included all individuals who self-reported race/ethnicity information that allowed us to identify URM applicants. 2) The excluded applicants (N = 501) did not report race/ethnicity information or only specified "other," which did not allow us to code them as URM or non-URM. Stars indicate the results of t-tests for the equality of means. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

nation. The application data available to us included self-reported information on gender, race, and ethnicity, which we used to identify URM for our analysis; this consists of applicants who reported their race/ethnicity as African American or Black, Hispanic or Latino, or American Indian or Alaska Native. Other information in the application includes university (undergraduate or graduate institution), department, expected graduation year, and details about the invention, including the category that it seemed most appropriate for (Eat it!, Cure it!, Use it!, or Move it!).

Not all applicants reported race/ethnicity. Information was available to code each applicant as URM or non-URM for 78% of applicants (out of the 2,172 total applicants, race/ethnicity was missing for 474, and another 27 selected "other" without further information). Table 2 compares characteristics of applicants in our sample and those we had to exclude due to missing race/ethnicity information. There are some variables for which they differ, particularly the share that is female, but not others, such as the major field of study. Table 3 shows the share of applicants in each racial/ethnic category and other summary statistics for our sample. Note that the URM and non-URM groups are mutually exclusive, so multi-category race/ethnicity self-reporting was put into a separate category. Approximately 14% of the sample is URM, which far exceeds the estimates that roughly 5% of U.S. patent holders (regardless of gender) are a race other than Asian or White.

We merged higher education data from the federal Integrated Postsecondary Education Data System (IPEDS) to examine whether there are differences in the institutional characteristics of the colleges/universities attended by URM applicants as compared

Table 3. Summary Statistics of Applicants (N = 1,671)

	Mean	Std. Dev.
White	0.534	0.499
Asian	0.373	0.484
Hispanic	0.092	0.289
Black	0.042	0.200
Native American/Indig.	0.012	0.109
URM	0.141	0.348
Female	0.289	0.454
Undergrad	0.717	0.451
STEM Major	0.870	0.337
Public	0.487	0.500
Research Univ. (R1/R2)	0.876	0.330
Prize Category		
Cure it! (Health)	0.471	0.499
Eat it! (Food)	0.147	0.354
Move it! (Transport)	0.078	0.268
Use it! (Consumer)	0.304	0.460
Prize Year		
2014	0.081	0.274
2015	0.045	0.207
2016	0.098	0.297
2017	0.154	0.361
2018	0.199	0.400
2019	0.101	0.301
2020	0.166	0.373
2021	0.156	0.363

to non-URM applicants. IPEDS is the data collection program from the U.S. Department of Education's National Center of Education Statistics (NCES). IPEDS collects data from all higher education institutions that participate in the federal student aid program on an annual basis. We examined the following IPEDS institutional characteristics for our analysis: Basic Carnegie Classification and the Sector of Institution. The Basic Carnegie Classification categorizes all degree-granting higher education institutions into classifications that include, but are not limited to, Doctoral University: Very High Research Activity (R1); Doctoral University: High Research Activity (R2); and Master's Colleges and Universities: Larger Programs (M1). The Sector of Institution variable categorizes higher education by public or private institution and by two-year or four-year institution (16).

We also compared the data for LMIT Student Prize applicants to nationwide demographic data for U.S. students in majors prone to patenting. For this analysis, we used data from the National Science Foundation's and National Science Board's report *Science and Engineering Indicators 2019*, specifically Table S2-12, "Degrees awarded to U.S. citizens and permanent residents, by degree level, sex, race, ethnicity, and field: 2000 and 2017" (17). We combined fields into four major categories: engineering; natural sciences; social, behavioral sciences; and non-science and engineering majors.

For most of the analysis, we divided the LMIT applicant sample with race information into groups by race and gender to show how they differ. We created four groups using the race/ethnicity and gender information: non-URM women, URM women, non-URM men, and URM men. In addition to providing descriptive statistics about the differences across groups, we used ordinary least squares (OLS) regression analysis. We estimated the following regression to understand whether there were statistically significant differences in the focus of inventions by race and gender:

$$Prize\ Category_i = \propto + \beta_1 NonURMwoman_i + \beta_2 URMwoman_i + \beta_3 URMman_i + \varepsilon_i$$

where for each applicant i, Prize Category was a binary variable for each of the four prize types that the applicant's invention could be assigned to. We included controls for undergraduate/graduate students and application year (cohort). The β coefficients reflect differences in the likelihood of individuals from the groups to apply to the prize category relative to non-URM men. In another specification, we additionally included indicator variables for broad major fields of study of the applicant and for whether the applicant attended a public or private institution.

RESULTS

Application Rates

Figure 1 shows the share of prize applicants who reported being from a URM group from 2014 to 2021. Here, we see that the share of URM applicants does not exceed 25% of the share of applicants for each applicant period. There is a gradual increase of URM undergraduate applicants over time, with URM graduate student applicants showing an overall increase from 2014 to 2021, but a decline in graduate student applicants from the previous year in the applicant years of 2017, 2018, and 2019. More active outreach was conducted to identify promising student inventors starting with the 2018 prize cycle, suggesting that discovery tools or methods are an important part of being able to identify student inventors from diverse backgrounds and that the potential exists for fostering diversity in the patent process through a more

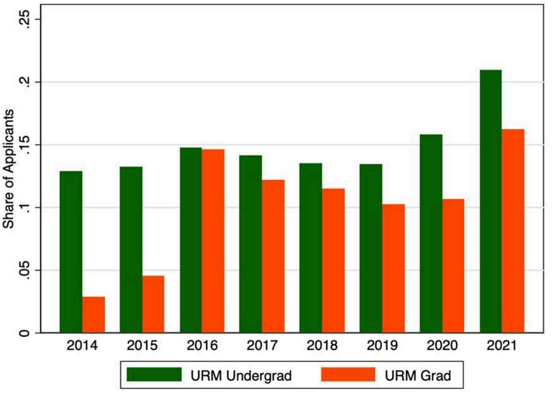

Figure 1. The share of graduate and undergraduate prize applicants who are URM, 2014–2021. (Note: The sample used in the analysis (N = 1,671) included all individuals who self-reported race/ethnicity information, which allowed us to identify URM among undergraduate and graduate applicants.)

intentional approach of identifying and featuring collegiate student inventors from diverse backgrounds (18).

In Table 4, we show the same summary statistics as in Table 3 separately for URM and non-URM applicants. Most striking is that the gender gap is quite similar among URM and non-URM student inventors, with 29% of both URM and non-URM being female. We note that among those who chose to not report racial/ethnic information, the gender gap is larger, with only 20% of those with no racial/ethnic information being female. This means that women are more likely to report race/ethnicity, so there are fewer of them in the "no information" group.

We note some important differences between the URM and non-URM prize applicants. First, URM applicants are disproportionately likely to be undergraduates. This reflects the larger racial/ethnic gap among the graduate students: While 15% of the undergraduate applicants are URM, only 11% of the graduate applicants are URM. The differences in field of study are evident in Table 4, with URM less likely to come from engineering fields than non-URM applicants (a difference of almost 10 percentage points); also, URM applicants are five percentage points less likely to come from research universities. Finally, it is already evident that there are striking differences by prize category, with URM applicants less likely to be inventing in the health care prize category and more likely to be inventing in consumer products and devices. We explore these differences by race and gender in the following sections.

Type of Invention

We next examined the invention types by looking at the distribution of applicants across the four prize categories for each race-gender group. Figure 2 shows striking differences in what URM inventors

Table 4. Summary Statistics for URM/Non-URM Applicants

	Non-URM	URM	Difference
Female	0.290	0.288	0.001
Undergrad	0.708	0.771	-0.063*
STEM Major	0.836	0.726	0.110**
Field of Study			
Engineering	0.584	0.486	0.098*
Computer Sciences	0.129	0.103	0.027
Biological Sciences	0.063	0.068	-0.006
Public	0.480	0.526	-0.046
Research Univ. (R1/R2)	0.884	0.826	0.057*
Prize Category			
Cure it! (Health)	0.490	0.360	0.130***
Eat it! (Food)	0.144	0.165	-0.021
Move it! (Transport)	0.076	0.089	-0.013
Use it! (Consumer)	0.290	0.386	-0.095**
Prize Year			
2014	0.085	0.059	0.026
2015	0.047	0.034	0.013
2016	0.097	0.102	-0.005
2017	0.155	0.148	0.007
2018	0.202	0.182	0.020
2019	0.102	0.089	0.013
2020	0.166	0.169	-0.004
2021	0.146	0.216	-0.070**
Observations	1,435	236	

Note: Columns present means for each group. Stars indicate the results of tests of proportions and *t*-tests for the equality of means. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

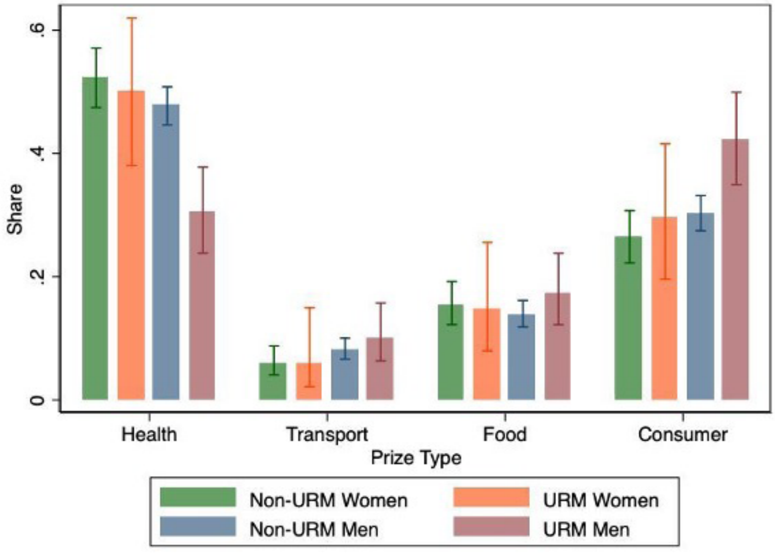

Figure 2. The share of applicants from each race/gender group across prize type categories. (Note: This figure shows the share of applicants from each race and gender group for each prize type category. Bars include logit-transformed 95% confidence intervals.)

Table 5. Regression Estimates: Focus of Inventions by Gender and Race

	Health (Cure it!) (1)	Transport (Move it!) (2)	Food (Eat it!) (3)	Consumer (Use it!) (4)
(Omitted: Man, non-URM)				
Woman, non-URM	0.060*	-0.030*	0.011	-0.041
	(0.029)	(0.014)	(0.021)	(0.026)
Woman, URM	0.046	-0.032	-0.004	-0.010
	(0.061)	(0.029)	(0.043)	(0.057)
Man, URM	-0.153**	0.015	0.029	0.109**
	(0.038)	(0.024)	(0.031)	(0.041)
N	1653	1653	1653	1653
Mean of Dep Variable	0.472	0.077	0.146	0.304
r2	0.070	0.024	0.026	0.030

Note: Estimation is by OLS with robust standard errors. Dependent variables are binary indicators for each of the four prize categories. Controls include undergraduate indicators and cohort indicators. All estimates are relative to the omitted category (non-URM men). $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

are working on and clear differences at the intersection of gender and race. It shows that URM men are much less likely to work on health inventions (first group of bars) compared to all other groups, and they are much more likely to work on consumer-oriented inventions than all other groups (last group of bars). Also striking is that URM women are quite similar to non-URM students in being most likely to work on health care inventions.

Regressions in Table 5 show that these differences are statistically significant after controlling for undergraduate/graduate applicants and year of application. They show that URM men are over 15 percentage points less likely to apply to the health category compared to non-URM men. Meanwhile, they are 10 percentage points more likely to apply to the

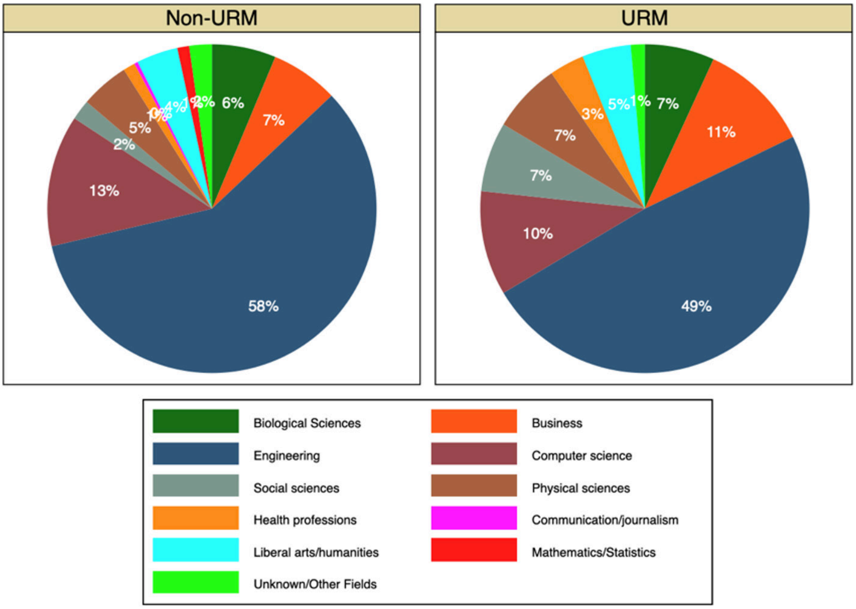

Figure 3. Share of applicants from each major/department for URM and non-URM applicants. (Note: This figure shows the distribution across major fields of study as reported by applicants.)

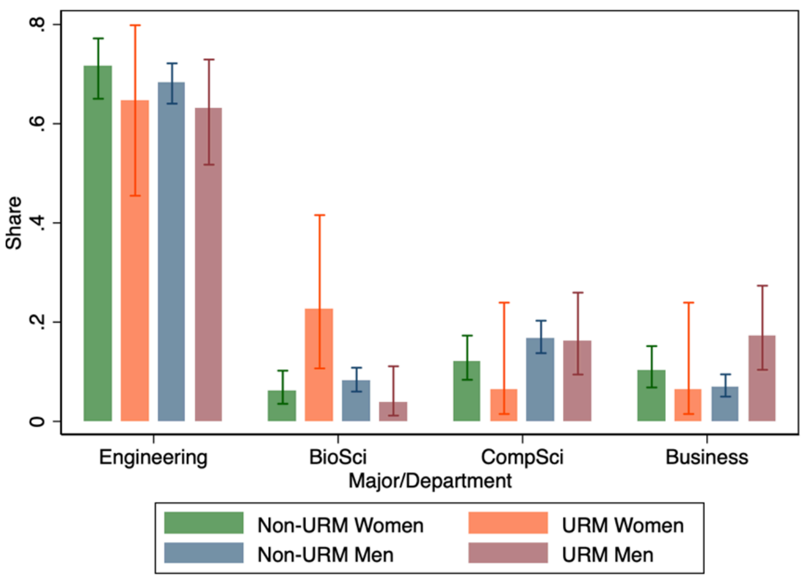

Figure 4. The share of applicants from each race/gender group across majors/departments. (Note: This figure shows the share of applicants by race and gender for each major academic discipline category. Bars include logit-transformed 95% confidence intervals.)

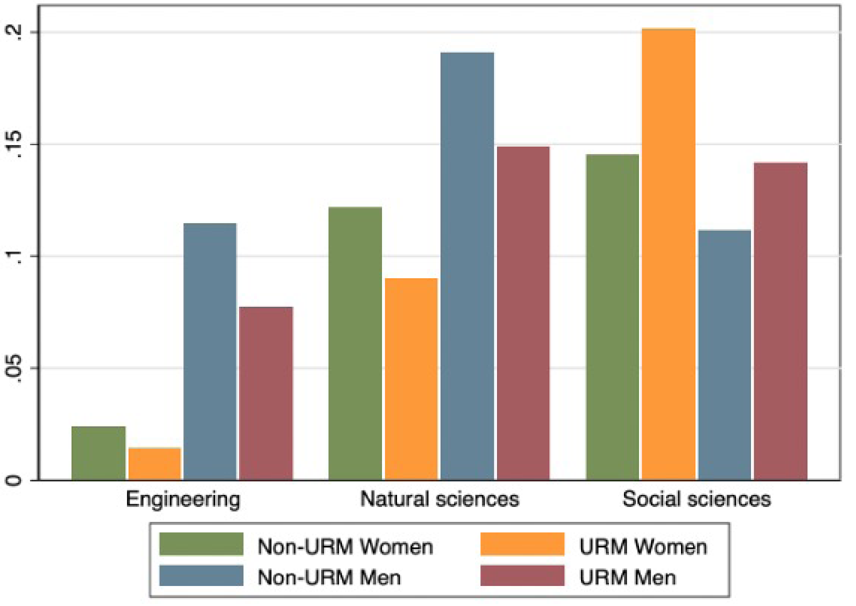

Figure 5. The share of STEM bachelor's degrees awarded to URM and non-URM students nationally in 2017. (Note: Data for 2017 bachelor's degrees awarded by S&E field comes from the NSF's and NSB's report *Science and Engineering Indicators 2019*.)

consumer devices or products category compared to non-URM men. We also see that there are few significant differences among the other groups. We will try to understand these raw differences more carefully later to understand the extent to which differences in the fields of study and types of institutions that applicants come from can explain these differences.

Fields of Study

The differences in the focus of inventions by URM and non-URM applicants may reflect differences in the major fields of study. In Figure 3, we show the distribution of both URM and non-URM prize applicants across fields. As discussed for Table 4, we see that URM applicants are less likely to come from engineering fields than non-URM applicants (58% of non-URM vs. 49% of URM). We can also see that URM applicants are slightly less likely to come from computer science fields and more likely to come from business and social science fields.

Figure 4 shows the share of each race-gender group across the four largest major fields of study (engineering, computer science, biological sciences, and business). Both female and male URM are less likely to be in engineering fields. Yet we find differences again by examining the intersectionality of race and gender, with male URM student inventors more likely than the other groups to major in the non-STEM field of business (last group of bars). Female URM student inventors, meanwhile, are more likely to major in the biological sciences than the other groups, pointing to an important reason for the high representation of URM women applying to the health care prize category.

Are the differences in major fields of study by gender and race consistent with data on bachelor's degrees awarded by broad majors at colleges and universities across the United States? In Figure 5, we present the shares of URM and non-URM men and women across broad fields of study in 2017 from the NSF's and NSB's *Science and Engineering Indicators 2019* report. First, we see that in the national data,

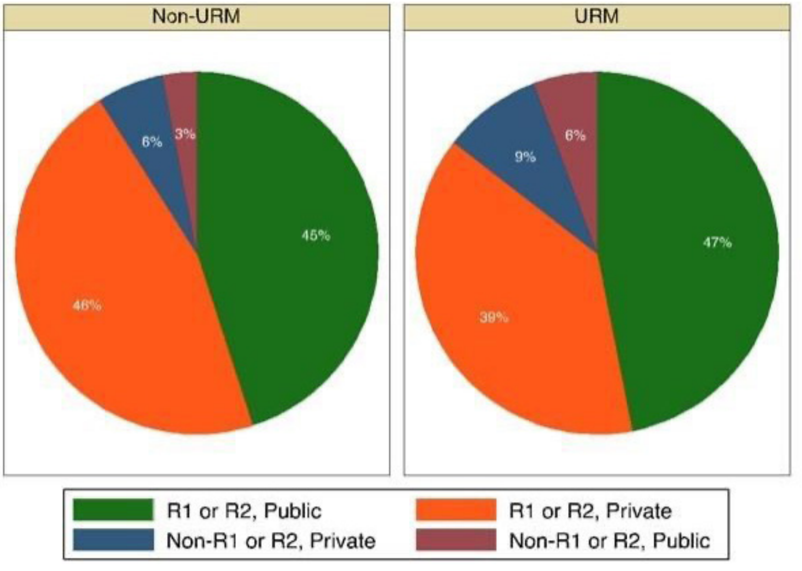

Figure 6. Share of non-URM and URM applicants by the type of institution enrolled in. (Note: Basic Carnegie Classification using data from IPEDS from the U.S. Department of Education's NCES.)

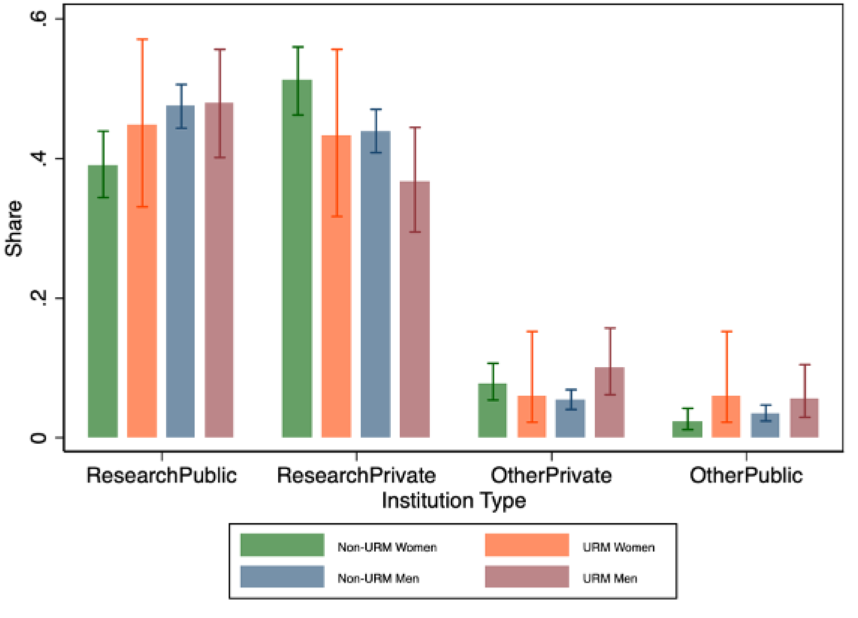

Figure 7. The share of applicants from each race/gender group across types of institution. (Note: This figure shows the share of applicants from each race and gender group across institution type. Bars include logit-transformed 95% confidence intervals.)

URM women are less likely to come from the natural sciences compared to the other groups, with about 9% of URM women degree holders graduating with a natural sciences degree. We also see that a larger share of URM men graduated with a natural sciences degree compared to both groups of women; specifically, almost 15% of URM men graduated with a natural sciences degree in 2017. These patterns are quite different from the LMIT Student Prize applicant data where, compared to the other groups, URM women were more likely to be studying the biological sciences, while URM men were less likely.

Figure 5 also shows that URM men are more likely to graduate from engineering fields compared to both URM and non-URM women. This pattern is also different from the LMIT Student Prize applicant data, where URM men were similar to URM women and were less likely to come from engineering fields than non-URM women applicants.

This suggests that national enrollment patterns are likely not fully explaining the differences in fields of study that we are observing in the applicant data.

Type of University

We next examined the types of universities where URM applicants are enrolled compared to non-URM applicants. Figure 6 shows the share of URM and non-URM in each of four types of universities using the Basic Carnegie Classification: public research university (R1 or R2), private research university (R1 or R2), public other university, and private other university. We see that a slightly larger share of URM applicants are from public research universities (47% vs. 45%). Meanwhile, only 39% of URM applicants are from private research universities vs. 46% of non-URM. A slightly higher share of URM applicants

Table 6. Regression Estimates: Focus of Inventions by Gender and Race with Controls

	Cure it! (1)	Cure it! (2)	Cure it! (3)	Use it! (4)	Use it! (5)	Use it! (6)
(Omitted: Non-URM Men)						
Non-URM Women	0.080*	0.066+	0.063+	-0.026	-0.013	-0.014
	(0.036)	(0.037)	(0.037)	(0.033)	(0.034)	(0.034)
URM Women	0.003	-0.025	-0.022	-0.006	0.004	0.004
	(0.083)	(0.082)	(0.080)	(0.073)	(0.074)	(0.074)
URM Men	-0.140**	-0.133**	-0.121*	0.084	0.073	0.073
	(0.047)	(0.049)	(0.049)	(0.053)	(0.054)	(0.054)
Major Field of Study						
Biological Sciences	0.367**	0.342**	0.340**	-0.309**	-0.310**	0.310**
	(0.067)	(0.068)	(0.068)	(0.055)	(0.057)	(0.057)
Business	-0.059	-0.096	-0.092	0.076	0.087	0.087
	(0.060)	(0.062)	(0.061)	(0.071)	(0.074)	(0.074)
Computer Science	0.025	0.010	0.006	-0.085	-0.091	-0.091
	(0.053)	(0.055)	(0.055)	(0.057)	(0.058)	(0.058)
Engineering	0.171**	0.150**	0.152**	-0.134**	-0.135**	0.135**
	(0.040)	(0.043)	(0.042)	(0.043)	(0.044)	(0.044)
Public Institution		-0.034	-0.047		0.017	0.016
		(0.031)	(0.032)		(0.030)	(0.030)
R1 or R2			0.133**			0.005
			(0.041)			(0.045)
N	1000	957	957	1000	957	957
Mean of Dep Variable	0.419	0.425	0.425	0.323	0.324	0.324
r2	0.090	0.088	0.096	0.071	0.075	0.075

Note: Estimation is by OLS with robust standard errors. Dependent variables are binary indicators for either the health or consumer device prize categories. Additional controls not presented include undergraduate indicators and cohort indicators. All estimates are relative to the omitted category (non-URM men). + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table 7. URM Student Prize Winners by College/University Attended (2014–2021)

College/University	Undergraduate URM	Graduate URM	Total URM
Duke University	0	1 Female	1
Massachusetts Institute of Technology	2 Males	1 Male	3
New York University	0	1 Female	1
University of California, Berkeley*	1 Male	0	1
University of Iowa*	1 Male	0	1
Total	4 URM winners	3 URM winners	7
% of Total Winners	6% of Undergraduate Team winners	10% of Graduate Winners	7% of Total Winners

Note: Includes number of URM prize winners based on self-reported race and gender. * Denotes public universities.

Table 8. URM and Gender of Student Prize Winners (2014-2021)

	URM Women	URM Men	Non-URM Women	Non-URM Men	Total Winners
Undergraduate	0	4*	24	43	71
Graduate	2	1	12	14	29
Total Winners	2	5	36	57	100

Notes: *2 of 4 URM undergraduate men attended a public university

come from the non-research universities (both public and private).

In Figure 7, we look at the distribution across the race-gender groups. The first group of bars shows that both male and female URM are more likely to come from public research universities. The second group shows that URM men are the least likely to come from private research universities. In the third group, URM men are slightly more likely to also come from other private universities compared to other groups. This likely reflects the higher share of URM men coming from business fields.

Do Field of Study and Institution Explain The Differences in LMIT Student Prize Applicants?

We now return to the analysis of the invention types in Figure 2 and Table 5, where we showed that URM men applicants were different from the other groups, as they were less likely to apply to the Cure it! (health care) category and more likely to apply to the Use it! (consumer devices and products) category. In Table 6, we ran the same regressions as in Table 5, but we added controls for the individual's broad field of study (Columns 1 and 4), whether they attended a public university (Columns 2 and 5), and whether they attended an R1/R2 research university (Columns 3 and 6). The coefficients of interest are the URM men indicator. We see that controlling for major and university does not change the negative coefficient much for the Cure it! prize category, so that even controlling for major and university type, URM men are still 12 percentage points less likely to apply to the health care category. This suggests that there are other factors — beyond differences in majors and institutions — that are leading to the differences in URM men's likelihood of applying to this category. The coefficient for the URM men indicator for the consumer devices category is no longer significant and is smaller in magnitude although it is still positive. This suggests that the major field of study and institution type are likely explaining much of this gap for the consumer devices category. We note that the R2 is low in these regressions, which suggests that including other variables in the analysis could help us better understand overall what determines whether an applicant is working in a specific area.

We were limited, however, by information available in the application data.

Is Type of Institution Correlated with the Likelihood That Applicants Will Win a Prize?

Prize award data for the time period examined for this study (2014 to 2021) indicates that all URM applicants winning the prize attended research universities, and two of the five universities with URM prize winners are public research universities. Table 7 shows the universities attended by the seven URM winners at the graduate and undergraduate levels. The URM winners constituted 7% of total winners (seven URM of both genders out of 100 winners) across the graduate and undergraduate categories. The proportional representation of URM winners was highest at the graduate level, with three URM winners of 29 total graduate winners (10% of total). The URM graduate students constituted 11% of the total graduate applicant pool. URM undergraduates were 6% of total undergraduate student winners even though they constituted 15% of total undergraduate applicants. The differential representation of URM graduates compared to URM undergraduates among prize winners may suggest that more URM could be active contributors to patenting in the United States if they continued to develop and be supported beyond their undergraduate years.

Table 8 offers additional details about the male versus female URM winners. The greater absolute number of male URM winners at the undergraduate level, with a team-based award, may be an indication that team-based approaches to invention at colleges and universities offer opportunities for inclusion.

CONCLUSION

Our analysis shows that applications for a national collegiate prize for invention included a high percentage of URM students when compared to the percentages of URM inventors in the general population and that URM men were more represented in the consumer device category. In understanding what fields of study and which institutions URM applicants are coming from, we show that URM men are coming from fields of study that go beyond the STEM fields prone to patenting and that URM applicants also included a large number of students from public universities and higher education institutions that are not among those designated as R1 or R2 (i.e., research-intensive universities).

Our results provide descriptive facts about a specific group of college students to inform understanding of diversity among students on this part of the pathway to invention. The analysis offers insights into what could be gained from further research. While the sample of applicants to this prize is not representative of all student inventors nationally, understanding diversity among this group provides glimpses into the early experiences of those pursuing a “pathway” that can lead to an invention. Our findings suggest that there are multiple pathways to invention, including work at research universities and two- and four-year colleges. Greater clarity surrounding the ways each of the types of educational institutions are supporting inclusivity can help URM students make informed decisions about where and how to invest their time and resources as they work to transition their good ideas into patentable inventions. Our analysis underscores the importance of looking at the intersectionality of gender and race as it relates to patenting activity and the development of inventors. Collecting this information on patents is an important policy consideration. Next, while we looked at broad categories of inventions and found that URM men tended to work on consumer goods, more research into the specific types of consumer goods will be important to better understand these differences. The applicants in our sample have already shown evidence of their inventiveness by having a tested prototype and thus are among the most likely to be future patent holders. The development of invention prototypes is a phenomenon that is not commonly reported in publications about inventors’ experiences during their collegiate years, and this sample allows us to expand our understanding about diversity among students engaged in these activities. Lastly, our analysis highlights the need for more understanding about the role of universities in terms of types of universities and specific policies or programs that may be helping to create more inclusive pathways to innovation. While our results show that more URM applicants are coming from public institutions, further research can probe to what extent public institutions are fostering student inventors from more diverse racial/ethnic backgrounds and whether private institutions appear to be important for supporting non-URM women. This would help inform policy efforts to locate and bring added support to URM students so that they are more likely to continue on the pathway to invention.

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REFERENCES

1. Cook LD, Kongcharoen C. The idea gap in pink and black. Cambridge (MA): National Bureau of Economic Research; 2010 [accessed 2021 Nov 1]. https://www.nber.org/papers/w16331. NBER Working Paper 16331.
2. Toole AA, Breschi S, Miguelez E, Myers A, Ferucci E, Sterzi V, deGrazia CAW, Lissoni F, Tarasconi G. Progress and potential: a profile of women inventors on U.S. patents. Alexandria (VA): U.S. Patent and Trademark Office; 2019 [accessed 2022 Feb 15]. https://www.uspto.gov/sites/default/files/documents/Progress-and-Potential-2019.pdf.
3. Koning R, Samila S, Ferguson JP. Who do we invent for? Patents by women focus more on women's health, but few women get to invent. Science. 2021;372(6548):1345–1348.
4. Einiö E, Feng J, Jaravel X. Social push and the direction of innovation. SSRN. 2019 [accessed 2022 Feb 15]. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3383703.
5. Cook LD, Gerson J, Kuan J. Closing the innovation gap in pink and black. Entrepreneurship Innov Policy Econ. 2022;143-66.
6. Hsieh CT, Hurst E, Jones CI, Klenow PJ. The allocation of talent and US economic growth. Econometrica. 2019;87(5):1439–1474.
7. Fechner H, Shapanka MS. Closing diversity gaps in innovation: gender, race, and income disparities in patenting and commercialization of inventions. Technol Innov. 2018;19(4):727–734.
8. Hunt J, Garant JP, Herman H, Munroe DJ. Why are women underrepresented amongst patentees? Res Policy. 2013;42(4):831–843.
9. Cook L. Policies to broaden participation in the innovation process. Washington (DC): Brookings Institution: The Hamilton Project; 2020 [accessed 2021 Nov 1]. https://www.hamiltonproject.org/assets/files/Cook_PP_LO_8.13.pdf. Policy Proposal 2020-11.
10. Fry R, Kennedy B, Funk C. STEM jobs see uneven progress in increasing gender, racial, and ethnic diversity. Washington (DC): Pew Research Center; 2021 [accessed 2021 Nov 1]. https://www.pewresearch.org/science/2021/04/01/stem-jobs-see-uneven-progress-in-increasing-gender-racial-and-ethnic-diversity/.
11. Ceci SJ, Ginther DK, Kahn S, Williams WM. Women in academic science: a changing landscape. Psychol Sci Public Interest. 2014;15(3):75–141.
12. Dasgupta N, Stout JG. Girls and women in science, technology, engineering, and mathematics: STEMing the tide and broadening participation in STEM careers. Policy Insights Behav Brain Sci. 2014;1:21–29.
13. National Science Board, National Science Foundation. Invention, knowledge transfer, and innovation. Science & Engineering Indicators 2020. Alexandria (VA): National Science Board, National Science Foundation; 2020 [accessed 2021 Oct 21]. https://ncses.nsf.gov/pubs/nsb20204. NSB-2020-4.
14. Reber S, Sinclair C. Opportunity engines: middle-class mobility in higher education. Washington (DC): The Brookings Institution; 2020 [accessed 2021 Oct 21]. www.brookings.edu/wp-content/uploads/2020/05/Opportunity-Engines_Final.pdf.

15. Chetty R, Friedman JN, Saez E, Turner N, Yagan D. Mobility report cards: the role of colleges in intergenerational mobility. Cambridge (MA): National Bureau of Economic Research; 2017 [accessed 2021 Oct 21]; https://www.nber.org/papers/w23618. NBER Working Papers w23618.
16. U.S. Department of Education. Integrated Postsecondary Education Data System (IPEDS), 2019 Institutional Characteristics. Washington (DC): Institute of Education Sciences, National Center for Education Statistics. [accessed 2021 Aug 15]. https://nces.ed.gov/ipeds/datacenter/InstitutionByName.aspx?goToReportId=1on 08/15/2021.
17. Science and engineering indicators. Alexandria (VA): National Science Board, National Science Foundation; 2019 [accessed 2021 Oct 21]. https://ncses.nsf.gov/pubs/nsb20197/data.
18. Bayer A, Wilcox DW. The unequal distribution of economic education: a report on the race, ethnicity, and gender of economics majors at US colleges and universities. J Econ Educ. 2019;50(3):299–320.