INVESTIGATING AND REMEDYING RACE DISPARITIES IN EDUCATION[‡]

Residential versus Online? Experimental Evidence on Diversifying the STEM Pipeline[†]

By SARAH R. COHODES, HELEN HO, ELIZABETH HUFFAKER, AND SILVIA C. ROBLES*

The rise of online academic courses and materials, spurred by the COVID-19 pandemic, has raised interest in the trade-offs of virtual versus in-person education. Much of the prior research has shown that students are less successful with an online modality (Figlio, Rush, and Yin 2013; Joyce et al. 2015; Alpert, Couch, and Harmon 2016; Kofoed et al., forthcoming) but that technology can facilitate access to educational opportunities that would otherwise be out of reach (Goodman, Melkers, and Pallais 2019). However, there is little evidence on the efficacy of online delivery of supplemental or enrichment programming. Such programs may not suffer from the same pitfalls as traditional education programming delivered online since

^{*}*Discussants:* Scott Carrell, University of California, Davis; Richard Mansfield, University of Colorado Boulder; Seth Gershenson, American University; Stephen Ross, University of Connecticut.

*Cohodes: University of Michigan (email: scohodes@ umich.edu); Ho: Chinese for Affirmative Action (email: research@helentho.com); Huffaker: Stanford University (email: huffaker@stanford.edu); Robles: Mathematica (email: srobles@mathematica-mpr.com). We are grateful to staff of and applicants and participants in the summer programs that are the subject of this paper, as well as the host institution and its institutional research office. Because the institution is anonymous, we unfortunately cannot thank the many people who supported this project by name. Their commitment was instrumental to this experiment, as was feedback and suggestions from Joshua Angrist, Lawrence Katz, and Amanda Pallais. We thank the Alfred P. Sloan Foundation, the Teachers College Provost's Investment Fund, the National Center for Institutional Diversity at the University of Michigan, the Lab for Economic Applications and Policy at Harvard University, and the National Science Foundation (award 1260898) for financial support. This study is registered in the AEA RCT Registry; the identifying number is AEARCTR-0002888.

 † Go to https://doi.org/10.1257/pandp.20241016 to visit the article page for additional materials and author disclosure statement(s).

they serve a highly motivated population. This paper directly tests this premise using a randomized controlled trial to contrast similar summer programs created to increase representation in STEM fields but provided as residential experiences versus primarily online. These STEM summer programs are run by and centered at the host institution (HI), an elite technical university, and serve high-achieving students, the majority of whom come from underrepresented minority (URM) backgrounds.

We find that only fully residential experiences produce large gains in STEM degree production. Even a relatively short residential program during high school increases persistence in STEM fields years later, suggesting a potentially profound role for in-person enrichment on major and career choices. Both the residential and online programs increase attendance at and graduation from competitive institutions. We could not fully attribute the differences in impacts to having in-person versus online college guidance programming because the online program also included several days of in-person college application-related events. However, these results suggest that even a few days of in-person college guidance with online supplementation can be highly effective for some outcomes of interest.

I. STEM Summer Programs at the Host Institution

Many organizations run STEM pipeline programs to address racial disparities in STEM education and careers, including the federal government (Granovskiy 2018), nonprofit organizations, and colleges and universities. The HI is one such institution, and it supports an office devoted to outreach programs to increase diversity in STEM fields; we refer to this unit as the "outreach office." In the period we study (the summers of 2014–2016), the outreach office fielded three summer programs that varied in their length and modality (residential versus online). All of the summer programs aimed to diversify the STEM workforce and increase access to STEM careers by exposing students to high-achieving peers, STEM mentors, STEM curriculum, tours of a college campus and research facilities, and college admissions information. The programs are free to students (funded by the HI, in some cases via specific gifts) except for transportation to and from the HI. The three programs are:

- Six-week program (residential, 80 students/ year): The six-week program mimicked the first year of college at the HI, with rigorous STEM-focused coursework and students living in dorms at the HI. In addition, students took tours of labs and workspaces at the HI; attended workshops with leaders of industry, academics, and admissions officers; and interacted with teaching assistants who are current college students. Students also visited STEM-focused companies and workplaces.
- One-week program (residential, 75–120 students/year): The one-week program was designed to expose students to a similar experience as the six-week program in a shorter time frame. Participants enrolled in a one-week STEM-focused enrichment course and also participated in similar complementary programming as in the six-week program.
- Online program (150–175 students/year): The online treatment used an online course platform to interact with students over six months, with a short visit to the HI campus during the summer. The online summer program provided top-down content in the form of videos, articles, or webinars, as well as small-group mentoring and interaction. Students also completed project-based engineering assignments. The campus visit was four to five days, during which students presented their projects, attended college admissions panels, and met their classmates in person.
- *Control condition*: Students randomly assigned to the control condition also applied to the HI's summer programs

but were not offered a chance to participate. According to surveys collected for this study, some of these students participated in alternative STEM summer programming. Many work or study over the summer.

For the purposes of this study, we combine the six-week and one-week programs into a single group, called "residential," to focus on the contrast between programs that are entirely in person with those that are primarily online.

II. Data, Research Design, and Estimation

A. Data

The analysis examines college application and admissions information from the HI and college enrollment information from the National Student Clearinghouse (NSC). The outreach office provided program applications with background information on applicants, applicant ratings, and details on program offers and participation. The NSC also reports information on graduation and majors. We observe college outcomes up to the spring of 2023 (see online Appendix Figure A.1 for outcome timing), which allow us to observe college graduation within six years of high school graduation, assuming on-time progress.

B. Research Design

All applicants from 2014 to 2016 were admitted via conditional random assignment (Cohodes, Ho, and Robles 2022a). The application was similar to those used for college admissions; for example, they included essays and letters of recommendation. With an initial screening, the applicant pool was narrowed to about 700 students in the target populations for the program with sufficient academic preparation. These students were rated by selection committees made up of program stakeholders, community members, and affiliates with long-standing ties to the outreach office. The selection committees ranked applicants in terms of suitability for the six-week program and provided separate scores for academic preparation and personal circumstances, taking into account factors that may have limited access to STEM in the applicant's background.

VOL. 114

The HI institutional research office used these scores to create a weighted ranking variable that accounted for these factors, as well as geography (to ensure broad geographic representation in the program), and then used this ranking variable to separate applicants into two groups: the highest rated group (Block 1) and the next rated group (Block 2), which had slightly lower rankings but was still suitable for the programs. To ensure gender balance in the programs, there were different ranking cutoffs for girls and boys. The institutional research office then conducted randomization within these blocks, so that applicants in Block 1 were randomized among the three programs and applicants in Block 2 were randomized to the online program or a control group. This procedure met the outreach office's preference for the highest-ranked students to be offered program seats while still allowing for randomization. A more detailed description of the selection and randomization processes is provided in Cohodes, Ho, and Robles (2022b) and its online Appendix, which includes details on some slight deviations from this randomization structure in the 2014 cohort.

This design enables two comparisons that rely solely on random assignment: (i) a comparison between residential programs (the six-week or one-week program) and the online program, taking advantage of the underlying random assignment in Block 1, and (ii) a comparison between the online program and control group, using the underlying random assignment in Block 2. We pool the two residential programs into one group in the main analysis, with estimates that separate the programs available in online Appendix Tables A.3 and A.4.

C. Estimation

We use random assignment to program offers to estimate the causal effect of assignment to either a residential or an online STEM summer program. We first compare students who are randomly assigned to either a residential program or an online program and interpret it as the treatment effect of residency compared to a program that is mostly online:

(1)
$$Y_i = \beta_r Residential_i + \sum_{j=1}^J \delta_j R_{ij} + \mathbf{X}'_i \gamma + \epsilon_i$$
.

We also compare applicants randomly assigned to the online program to a control group, as follows:

(2)
$$Y_i = \beta_o Online_i + \sum_{j=1}^J \lambda_j R_{ij} + \mathbf{X}'_i \omega + \eta_i.$$

In each case, Y_i is an outcome of interest for applicant *i*, such as graduation, and *Residential*_{*i*} and Online, are indicators for random assignment to an offer of treatment for a residential or online program. The β coefficients reveal intent-to-treat estimates of program offers. In the case of equation (1), β_r shows the difference between applicants offered a residential program and those offered an online program, and in equation (2), β_o shows the difference between applicants offered the online program and those assigned to a control group. In both cases, these are intent-to-treat estimates, with most students attending their assigned program. To increase precision, we include a vector of student-level control variables, X_i , including GPA, standardized math scores, race/ethnicity, and free and reduced-price lunch status. To account for differences across program years, preferences for the programs to enroll equal numbers of boys and girls, and regional preferences, we include randomization strata, R_{ij}. Randomization strata are mutually exclusive indicators for each group created by gender, regional priority, and program year. Regional priorities occur to increase geographic diversity and to make sure there are sufficient students for location-specific funding opportunities. Program offers are randomized within these strata. We use heteroskedasticity robust standard errors.

In contrast to our estimation strategy in Cohodes, Ho, and Robles (2022b), we rely only on pure randomization for our estimates of program effects here and do not directly compare the residential programs to the control group. We show in panel A of online Appendix Tables A.1 and A.2 that randomization resulted in study arms that were very similar in terms of their demographic characteristics and academic credentials. In panel B, we show that all students are equally likely to appear in the NSC data used for follow-up. In both cases, this is reassuring that randomization was successful and resulted in quite similar groups. To generate estimates of the residential program in contrast to the control group-a comparison we do not have a direct

	Attended in year 1		Graduated by year 4			Graduated by year 6		
	Any (1)	Competitive (2)	Any (3)	Competitive (4)	In STEM (5)	Any (6)	Competitive (7)	In STEM (8)
Panel A. Block 1: Residential versus online $[N =$	504]							
Residential	0.020 (0.022)	$0.052 \\ (0.048)$	$\begin{array}{c} 0.032 \\ (0.039) \end{array}$	$\begin{array}{c} 0.054 \\ (0.045) \end{array}$	$\begin{array}{c} 0.062 \\ (0.045) \end{array}$	$0.026 \\ (0.026)$	0.042 (0.038)	$\begin{array}{c} 0.089 \\ (0.049) \end{array}$
Online mean	0.891	0.631	0.594	0.451	0.425	0.783	0.565	0.512
Panel B. Block 2: Online versus control $[N = 1,$	327]							
Online	0.014	0.092	0.028	0.045	0.038	0.040	0.094	0.030
	(0.017)	(0.037)	(0.027)	(0.039)	(0.026)	(0.019)	(0.039)	(0.022)
Control mean	0.877	0.475	0.560	0.356	0.392	0.773	0.428	0.517
Panel C. Residential versus control $(\beta_r + \beta_o)$								
Residential	0.033 (0.036)	0.144 (0.055)	0.061 (0.057)	0.099 (0.057)	$0.100 \\ (0.057)$	$0.066 \\ (0.046)$	0.136 (0.057)	$\begin{array}{c} 0.119 \\ (0.058) \end{array}$

TABLE 1—THE IMPACT OF RANDOM ASSIGNMENT TO STEM SUMMER PROGRAMS ON FOUR-YEAR COLLEGE ATTENDANCE AND GRADUATION

Notes: Each coefficient labeled by program is the estimate of the impact of assignment to either a residential (i.e., one-week or six-week in-person at HI) or online STEM summer program on the outcome indicated in the heading. All regressions control for randomization strata and a vector of characteristics including indicators for GPA, standardized math score, race/ethnicity, and free and reduced-price lunch status. The sample includes STEM summer program applicants who applied in 2014, 2015, and 2016 and passed an initial screen, who were then subject to random assignment. Panel A compares students assigned to a residential program versus the online program. Panel B compares the online program to a control group. The online and control means are adjusted for randomization strata. Panel C combines estimates from panel A and panel B using seemingly unrelated regression. Robust standard errors are in parentheses.

area of common support for—we use seemingly unrelated regression to add $\beta_{residential}$ and β_{online} . The samples for each β are different (though both comprise very high-achieving populations), so estimates from this strategy assume a lack of treatment heterogeneity across the sample populations.

III. Results

We present our findings on four-year college enrollment and graduation in Table 1. Panel A compares students randomly assigned to one of the residential programs with those randomly assigned to the online program. Panel B compares those randomly assigned to the online program with those assigned to the control group. Finally, panel C presents estimates of the total effect of the residential program compared to the control group, relying on assumptions that treatment effects can be extrapolated across the randomization blocks. In all cases, we refer to competitive institutions as those ranked in the highest-ranking category of Barron's rankings ("most competitive").

Neither the residential programs nor the online program affect enrollment at four-year colleges (column 1), but the programs shift students toward attending more selective colleges. The online program increased enrollment at the most selective colleges by 9 percentage points compared to the control. The residential programs increased competitive enrollment by 5 percentage points in contrast to the online program, though this difference is not statistically significant. The calculated total effect on competitive college enrollment of the residential programs versus the control is 14 percentage points and is statistically significant. The lack of strong effects on four-year college enrollment is not surprising given that almost 90 percent of control group members enroll in such institutions. However, there is room to induce enrollment in competitive colleges, even for this highly motivated and academically competitive group of students.

The estimated effects of the programs on on-time graduation for any four-year college are positive but not statistically significant (about 3 percentage points each for online compared to control and residential compared to online, and 6 percentage points for residential compared to control). The effects on on-time graduation at competitive four-year colleges are slightly larger but significant at the 10 percent level only for the contrast between residential programs and the control group (about 10 percentage points). Similarly, the estimated program impacts on on-time graduation with a STEM degree are positive but not statistically significant except for the additive effect of the residential and online programs where there is a 10 percentage point increase in on-time graduation with a STEM degree (significant at the 10 percent level).

Greater effects on graduation emerge when we turn to six-year graduation, the college completion metric prioritized by the National Center for Education Statistics. In comparison to the control group, the online program increased six-year graduation from any four-year college by 4 percentage points (significant at the 10 percent level) and from competitive institutions by 9 percentage points. While the estimates are positive, the residential programs do not seem to significantly build on this graduation advantage in comparison to the online program. Residential effects are about 3 percentage points for any college and 4 percentage points for competitive colleges; neither are statistically significant. The additive effect of the residential program over the control group in six-year graduation rates at competitive institutions is over 13 percentage points and is statistically significant.

A difference in STEM attainment also emerges when we observe six-year graduation. Compared to the online program, the residential programs increase STEM degree attainment by year 6 by 9 percentage points and is significant at the 10 percent level. In contrast, the online program only leads the control group by 3 percentage points (not significant). The additive effect of the residential program on STEM degree attainment compared to the control group is 12 percentage points and is statistically significant.

IV. Conclusion

Both the online and residential programs are similarly effective at boosting six-year graduation, with especially large gains at competitive colleges. However, when it comes to the key goal of generating new STEM degrees, the residential programs have an advantage. Residential programs are more expensive than online programs, with back-of-the-envelope estimates of program costs around \$15,000 per student for the six-week program and \$2,000 per student for the one-week and online programs. However, the one-week and online programs rely on the infrastructure of the six-week program, making it difficult to estimate costs in the absence of the six-week program. Optimal program design thus depends on the goals of the policymakers and hosting institutions.

REFERENCES

- Alpert, William T., Kenneth A. Couch, and Oskar R. Harmon. 2016. "A Randomized Assessment of Online Learning." *American Economic Review* 106 (5): 378–82.
- Cohodes, Sarah, Helen Ho, and Silvia Robles. 2022a. "A Randomized Evaluation of STEM Focused Summer Programs." AEA RCT Registry. February 03, 2022. https://doi.org/10.1257/ rct.2888-2.1.
- Cohodes, Sarah R., Helen Ho, and Silvia C. Robles. 2022b. "STEM Summer Programs for Underrepresented Youth Increase STEM Degrees." NBER Working Paper 30227.
- Figlio, David, Mark Rush, and Lu Yin. 2013. "Is It Live or Is It Internet? Experimental Estimates of the Effects of Online Instruction on Student Learning." *Journal of Labor Economics* 31 (4): 763–84.
- Goodman, Joshua, Julia Melkers, and Amanda Pallais. 2019. "Can Online Delivery Increase Access to Education?" *Journal of Labor Economics* 37 (1): 1–34.
- Granovskiy, Boris. 2018. Science, Technology, Engineering, and Mathematics (STEM) Education: An Overview. Washington, DC: Congressional Research Service.
- Joyce, Ted, Sean Crockett, David A. Jaeger, Onur Altindag, and Stephen D. O'Connell. 2015. "Does Classroom Time Matter?" *Economics* of Education Review 46: 64–77.
- Kofoed, Michael S., Lucas Gebhart, Dallas Gilmore, and Ryan Moschitto. Forthcoming. "Zooming to Class? Experimental Evidence on College Students' Online Learning during COVID-19." American Economic Review: Insights.