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Long-Term Outcomes of RET Programs on Female and Minority Student High School Graduation Rates and Undergraduate STEM Major Rates (Fundamental)

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Long-Term Outcomes of RET Programs on Female and Minority Student High School Graduation Rates and Undergraduate STEM Major Rates

Introduction

According to the National Center for Education Statistics, Latinx populations are almost twice as likely to drop out of high school as their peers [1]. The lack of high school graduation for these students can be attributed to several factors such as school engagement, home and classroom environment, social and peer pressures, and academic problems [2]. Additionally, minority students and women who persevere in high school and elect to attend a college or university may select Science, Technology, Engineering, and Mathematics (STEM) majors; however, they tend to choose fields such as life and health sciences. The underrepresentation of women in engineering and earth sciences is chronically low at 20% and 40% of these majors, respectively. Black and Hispanic/Latinx students' representation is less than half of what would be predicted based on their population in the USA. Moreover, these students may initially choose a STEM major but decide to leave the field before graduating to satisfy racial and gender belongingness in higher education [3].

Research Experience for Teachers (RET) programs are National Science Foundation (NSF) funded programs independently designed to provide K-12 STEM teachers with immersive, hands-on research experiences at Universities around the country. The Rice University RET program in Nanotechnology provides a six-week summer research internship for at least 12 Houston-area teachers each year since 2010 [4]. Participants learn about the latest technological advances in nanotechnology from Rice University faculty and how to communicate with technical and non-technical audiences. RET programs are typically 40 hours per week of paid internships where teachers conduct discovery research, probe new questions in science and engineering, and are immersed in the process of science. This RET in Nanotechnology goes beyond the summer and supports the teachers during the academic year with Saturday curriculum workshops for over 260 contact hours. A significant consideration for funding NSF RET programs is that the proposal emphasizes broadening the participation of underrepresented groups in engineering and computer science [5]. Our RET program prioritizes teachers who teach at high-needs schools and encourages teachers to translate high-level research content into inquiry-driven, Project-Based Learning (PjBL), engineering, and culturally relevant curriculum that fit the specific needs of the students they serve.

To ensure the alignment of the independent RET program's goals and the NSF's objectives, various university RET programs have utilized evaluation methods that capture short-term data such as the program's impact on the teacher or lesson plan implementation with diverse populations. This paper investigates the connection between our RET program and long-term female and minority student achievement in the forms of high school graduation rates and undergraduate STEM major selection rates using a state agency K-12 and higher education database. As a comparison, state agency data from students of nonRET teachers within the same schools and grade-level were utilized. This study is a proof of concept paper that tests whether it is possible to use these state-wide databases to longitudinally evaluate student graduation rates and the choice of STEM majors in college in relation to a RET teacher professional development program (PD).

Literature Review

NSF RET programs historically have been shown to build teachers' content knowledge through university-led programs to promote diverse representation in STEM majors [5]. Methods in which traditionally evaluated students' success could be categorized into measuring the program's impact on teachers, measuring the program's impact on student achievement, or measuring the effect on student's awareness of STEM and willingness to pursue STEM.

Measuring Program's Impact on Teachers

One method in determining a successful RET program's impact was by focusing on teacher classroom implementation's long-term impact. Most RET programs utilize immediate post-program teacher focus groups and surveys, distributed through external evaluators, to evaluate participants' content implementation plans, engineering knowledge, cultural responsiveness, and beliefs of various teaching methodologies [6,7,8,9]. Additionally, holding focus groups and distributing qualitative surveys to former participants of RETs can be utilized to measure the long-term program impact on teacher engineering knowledge [10]. One example of determining a RET programs' impact using focus group qualitative surveys. Analysis of our 2014- 2016 RET participants' self-efficacy using the Science Teaching Efficacy Belief Instrument (STEBI) within a prior study revealed the experiences significantly influenced ($p<0.05$) teachers' ability to contribute to student outcomes in science and at a gain of 6%.[4] Additionally, Texas A&M University's Enrichment Experiences in Engineering (E3) teacher research program collected surveys from former research participants from high school science and mathematics teachers to evaluate long-term program impact [10]. Findings of this long-term impact study suggest that the E3 program has been rewarding in educating teachers about engineering careers and promoting engineering to the students. Similarly, Columbia University's Summer Research Program (CUSRP) tracked the long-term teacher outcomes via survey after entry and completion of a two-year program each spring [11]. RET survey responses indicated participation in the CUSRP program provided a deeper connection to student learning experiences and encouraged teachers to utilize contextualized instructional practices with the classroom. Of the respondents, 96% increased hands-on activities, 83% introduced new lab technologies, and 65% promoted reading of scientific articles in the classroom. These examples focus on pre and post-surveys framed to assess the teacher participants' long-term program gains and their application in the classroom. Although these evaluation methods provide insight into how teachers benefit from RET programs and the RET's potential plans for engaging students in engineering topics, the impact on students' success in high school and STEM undergraduate major rate was lacking.

Measuring Program's Impact on Student Achievement

Minority student achievement rates in high school math and science create significant patterns that can help predict students' graduation rate and their willingness to pursue a STEM major [12,13]. Some RET programs attempt to measure their impact by documenting increases in student achievement on math and science standardized state tests. CUSRP, for example, focuses on the effect of students' science success through the State of New York Regents Science Examination. In the four years after the teacher's completion of the CUSRP, an increase of 15.5% more students passed the Regents science exam than non-participating teachers' students. This gain in student achievement was attributed to the teacher's ability to undertake new instructional techniques and apply experiences to their curriculum to meet students' needs.

Additionally, the Advanced Content in Computational Engineering and Science Standards for Teachers Research Experience for Teachers (ACCESS 4 Teachers RET) program uses a Science Qualitative Reading Inventory to assess science vocabulary, reading comprehension, and science writing achievement. Science literacy was a success measure correlated to other science fulfillment metrics such as Common Core standards, Next Generation Science Standards [14], or standardized statewide exams. The ACCESS 4 Teacher's RET evaluation results indicated that students of RETs had a 33.1% overall increase in Science Literacy scores across program years, which was statistically significant ($p < 0.05$), representing a much better result for students whose teachers participated in a RET program compared to those whose teachers didn't participate. Although increases in standardized test scores and science literacy may be useful to teachers, students, and communities, they do not provide exact matriculation rates of minority students pursuing STEM degrees as a predictor for student success.

Measuring Program's Impact on Student's Awareness of STEM and Willingness to Pursue STEM

Gathering data on student awareness of STEM careers through the lens of teacher surveys and focus groups after participation in a RET program has been a standard method used to assess program impact [15]. The increase in student willingness to pursue STEM as a career option has been one of many RET programs' primary goals. Post RET classroom activity feedback shows gains in student awareness of STEM and engineering applications, directly resulting from teachers feeling empowered and adequately equipped after attending RET programs. One such survey conducted by the E3 teacher research program gathered 2,000 student responses, which showed an increase in interest in pursuing an engineering degree in college after completing the teacher's program activities [10]. Unfortunately, surveys administered directly after the conclusion of a program to students do not seek to measure long-term student awareness in STEM and minimally address social relevance or the ethical implications of engineering [16]. Another example of RET evaluation is from the Loma Linda University (LLU) Summer Health Disparities Research Program. They published results on a high school teacher's research experiences to strengthen STEM representation of underrepresented minorities. LLU used a free-format of teacher narrative responses and interviews about the impact of the research internship on future goals concerning school/career, discovering an 80% increase of underrepresented minorities showing interest in STEM-related careers [17]. Acquiring student information that addresses student willingness to pursue STEM as a career preference was difficult due to teacher error in reporting long-term student information or students not responding to specified questions [10].

Addressing the Gap

At the time of this study, RET program evaluation measures tend to focus on the growth and development of teacher self-efficacy, engineering content knowledge gains, or classroom implementation of developed curriculum materials and students' attitudes toward STEM. To provide a better understanding of RET programs' impact on students, data are needed to show the long-term impact of PjBL RETs on student graduation rates and STEM undergraduate major selection rates. The study sought to inform RET program directors of utilizing student long-term tracking methods for evaluating program effectiveness. With access to a large-scale state-level student database, this study looks at RET programs' long-term impact in Texas on high school student graduation rates and undergraduate STEM major selection rates. Using the Texas Education Research Center database, we were able to identify RET teachers' students stretching back to the inception of the Nanotechnology RET at Rice University and examine the RET program's impact on a large scale.

The purpose of this study was to compare high school student graduation rates and undergraduate STEM major selection rates across gender, race, and ethnicity to a comparison sample. The comparison determined the Rice University RET program's long-term impact on students' likelihood of pursuing STEM careers. The following research questions guide this study:

1. Do students of RET teachers differ in high school graduation rates?
    a. Are differences consistent across gender?
    b. Are differences consistent across race/ethnicity?
2. Do students of RET teachers differ in undergraduate STEM major rates?
    a. Are differences consistent across gender?
    b. Are differences consistent across race/ethnicity?

Methods

RET Participants

We collected student data from primary and secondary teachers who participated in the Nanotechnology Rice University RET program between 2010-2019 using the Texas Education Research Center database. There were 115 teachers within the program, of which 92% taught at least one 8th - 12th-grade science or math course, and 70% were teachers at a Title I school. All teachers serve students within the Houston metropolitan area. Table 1 below provides the RET participant demographics from 2010-2019.

Table 1.

RET Participant Demographics 2010- 2019

	Gender		Ethnicity		Race				School Level		School
N	M	F	HISP	Non HISP	Asian	Black	White	Other	Primary	Secondary	Title I
115	41%	59%	16%	82%	14%	25%	43%	3%	7%	92%	70%

Accessing the Database

Texas Education Research Center (ERC) database [18] is a joint project between the Texas Education Agency (TEA), the Texas Higher Education Coordinating Board (THECB), the Financial Aid Database (FADS), the State Board of Educator Certification (SBEC), and the Texas Workforce Commission (TWC). The data system is a repository that contains the most comprehensive State Longitudinal Data system in the nation. The Texas ERC database provides researchers with teacher-linked student-level data that includes standardized tests, course work, graduation rates, and other valuable information to inform the school, district, and state education practices and policies. At this time, the database is only able to provide updates on students within Texas. Students choosing to attend college in other states are not reported.

High School Graduation Rates

RET student sample. Teacher identifying information was provided to the ERC oversight committee to classify them in the database. These teachers were then associated with the courses they taught for both the school year that they participated in the RET program and all subsequent years. Student course enrollment data were then merged into the teachers' database instructed by year, such that students in a given school year were matched to courses/teachers of those courses in that school year. Only students who were instructed by RET teachers either in the year of the teachers' participation in the RET program or years after the teachers' involvement were retained. Finally, based on students' grade level, we dropped students who would be expected to graduate after SY 2019-2020, e.g., a junior whom a RET teacher instructed in the school year 2016-2017 would be expected to graduate in the school year 2017-2018 and was retained, whereas a freshman instructed in 2017-2018 would have anticipated graduation of the school year 2020-2021 and would be dropped. This dataset provided the entire dataset of potential graduates instructed by RET teachers. There were N=11,240 students for RET teachers who could graduate in four years based on the school year of RET teacher instruction. These students were then mapped to a graduating student database. Students present in both databases are flagged as graduating, and students only appearing in the RET instruction database being flagged as not graduating. All data on teachers and students were de-identified in the ERC database. Student

demographics were self-reported to the database, with some students endorsing multiple racial/ethnic groups. The sum of race/ethnicity sample sizes exceeded the total sample size due to numerous endorsements.

Non-RET student sample. All students who were instructed in the same project years (2010-2019) as the RET programs but were not instructed by RET teachers and were eligible to graduate no later than SY 2019-2020 based on their grade level in schooling were retained as described above. These students were also mapped to the graduation database and flagged for graduation/not graduating in the manner described above. These students served as the basis for generating the comparison sample described below.

Comparison sample. To generate the comparison sample, we used a propensity score matching strategy. With propensity score matching, the outcome is whether students were in the treated group (instructed by RET teachers) or the comparison group. This binary outcome variable is predicted by a set of variables that potentially related to being in or absent from the treated group. We included campus, gender, race/ethnic status, and English proficiency status for the matched comparison sample. Model results provide a probability of being in the treated group based on these variables. We then matched students from the RET groups with non-RET students based on these probabilities. This matching resulted in balanced comparison samples of N=11,240 control students.

Data Analysis. We conducted a logistic regression using RET status to predict graduation. Logistic regression was chosen due to the outcome - graduation status - being binary. We conducted this analysis as a whole, gender, and separately for Asian American, Black, Caucasian, and Latinx students.

Undergraduate STEM Major Rates

RET student sample. The sample of students who were enrolled in RET teachers taught both the school year that teachers participated in RET and all subsequent years served as the basis for the undergraduate major sample. These students were then merged into a database containing all university, community college, private college/university students, and their declared major. Majors were listed by name, e.g., mechanical engineering, and an eight-digit numerical identifier known as a Classification of Instructional Programs (CIP) code. This college-level database contained multiple records per student, as students often change majors. For this sample, only the most recent declared major was retained. Finally, this database of students of RET teachers was mapped to a database from the Department of Homeland Security, which contained a list of all college major CIP codes deemed to be STEM-related. As such, we were able to produce a list of all students of RET teachers present in the college level database and to assign a flag variable indicating if the student endorsed a STEM major. The final dataset contained N=4,029 RET students.

Non-RET student sample. All students present in the college major database but were not instructed by RET teachers were retained. These students were also mapped to the CIP code database and flagged for STEM major/non-STEM major. These students served as the basis for generating the comparison sample described below.

Comparison sample. To generate the comparison sample, we used a propensity score matching strategy as described above. The binary outcome variable was predicted by age, campus, gender, and race/ethnic status. This matching resulted in a balanced comparison sample of N=4,029 control students.

Data Analysis. We conducted a logistic regression using RET status to predict STEM majors as indicated in the Texas Higher Education Coordinating Board's database. We conducted this analysis as a whole and by gender, separately for Asian American, Black, Caucasian, and Latinx students.

Results

High School Graduation Rates

All models were significant at $p<0.05$, with models being in favor of RET teachers' students compared to matched controls. As seen in Table 2 below, students of RET teachers had higher graduation rates than matched controls for the sample as a whole and all other subsamples; total (4.5%) and the male (4.8%), female (4.3%), Black (5.2%), Caucasian (7.0%), Asian American (3.9%) and Latinx (4.3%) students samples.

Table 2

Graduation rates for students of RET teachers versus matched controls.

Model	Gender	Sample N		Proportion STEM major	
		Non-RET	RET	Non-RET	RET
Total Sample*	All	11,204	11,204	0.778	0.823
Total Sample by Gender*	F	5,490	5,461	0.805	0.848
	M	5,750	5,779	0.752	0.800
Asian American Sample*		887	956	0.870	0.909
Black Sample*		2,736	2,718	0.777	0.829
Caucasian Sample*		5,391	5,425	0.768	0.806
Latinx Sample*		5,566	5,525	0.736	0.779

*Note: * = p <.05*

Undergraduate STEM Major Rates

As seen in Table 3, students of RET teachers had higher STEM major rates than matched controls for the sample as a whole (4.8%) and the male (4.2%), female (5.3%), Black (3.6%), and Caucasian (8.3%) samples. Concerning Asian American (4.2%) or Latinx (2.8%) students, differential STEM major rates did not meet the $p < 0.05$ threshold, but the effect was $p < 0.1$ and could be considered marginally significant [19]. As an additional note, the interaction effect for gender was at the $p < 0.1$ threshold, suggesting that it is possible that, when endorsing STEM majors, there was a greater benefit for women being instructed by RET teachers relative to men. Women of RET teachers majored in STEM, 5.3% more often relative to women who were not instructed by RET teachers, whereas men of RET teachers majored in STEM, only 4.2% more often relative to men who RET teachers did not teach.

Table 3.

STEM major rates for students of RET teachers versus matched controls.

Model	Gender	Sample N		Proportion STEM major	
		Non-RET	RET	Non-RET	RET
Total Sample*	All	4,029	4,029	0.179	0.227
Total Sample by Gender +	F	2,207	2,212	0.128	0.181
	M	1,822	1,817	0.240	0.282
Asian American Sample*		424	424	0.295	0.349
Black Sample*		1,180	1,184	0.152	0.188
Caucasian Sample*		1,086	1,085	0.170	0.253
Latinx Sample+		1,321	1,321	0.172	0.200

*Note: * = $p < 0.05$; + = $0.05 < p < 0.1$*

Discussion

High School Graduation Rates

Using the TEA database's longitudinal data provided a method for determining RET programs' effectiveness to focus on student graduation rates. RET students presented a favorable increase in graduation rates across gender and racially diverse populations through the RET. Students of NSF RET teachers are graduating at a higher rate than students of non-participating teachers. However, the data does not demonstrate if these higher graduation rates directly result from the NSF RET program itself or the teacher's overall proficiency.

We note that all graduation rates appear to be somewhat lower than expected. This lower rate was likely due to student mobility rates, on average 19% with school districts in the area, [19] with many students transferring before graduation. Thus, these seeming low graduation rates are an artifact of students simply exiting the population as a whole. The low graduation rates may also be related to our recruitment and selection process, where teachers were given priority if they taught in high-needs school districts (more than 40% of students on free or reduced lunch). Although this statistical artifact affects the overall report of graduation rates, we expect that it affects students of RETs and non-RETs in the same fashion and should have no impact on comparing RET teachers' students with students of non-RET teachers because the students are from the same schools. The analysis presented demonstrated the Rice University RET program's effect on RET program participants' student graduation rates. We found that students of RET teachers do differ in high school graduation rates. We also found that the difference between the graduation rate of Black students taught by RET teachers and non-RET teachers was higher (5.2%) than the difference between RET and non-RET teachers for the entire sample (4.8%), see Table 2. The Nanotechnology RET program at Rice University provided participants with PjBL, inquiry, and culturally relevant experiences to facilitate the connection between teacher and students with real-world context. RET programs similar to ours show increased self-efficacy, motivation for teaching, and teachers' willingness to incorporate higher-level process skills within the classroom [20,21,22,23]. Additional studies to determine if a change in the

teachers' course load, such as a higher percentage of Advanced Placement course, were conducted.

A comparison of elementary and secondary school RET instructors' impact on high school graduation rates was not conducted. From the data obtained, primary school RETs comprise a small percentage of the total distribution of participants. Students of elementary RETs are less likely to meet the graduation date requirement when data was collected, removing the population's elementary teachers.

STEM Undergraduate Major Selection Rates

The Nanotechnology RET analyzed STEM undergraduate major rates from the ERC database to determine the RET program's significance among students selecting STEM majors. The data appears to present a significant impact on female and minority students. Although there was a considerable difference in Black students' STEM major rates favoring RET teachers, data demonstrate an upward increase in undergraduate STEM major rates among Caucasian and female students. Research programs such as LA-STEM, where 53% of students served were women, reported an increased graduation rate among Black students interested in STEM [24]. The Texas Public Education Resource (TPEIR) highlights college application and enrollment trends of Texas public high school graduates who immediately applied to Texas public four-year colleges following high school graduation. TPEIR records indicate that minority students represented 23.7% of the graduating student population [25]. Although TPERI data does not indicate the percentage of accepted STEM majors, the Nanotechnology RET hopes to increase student college acceptance rates by recruiting teachers from Title 1 schools that directly serve them. Previous studies suggest fewer women and minorities are likely to pick a STEM major and are less likely to remain in that major [26].

RET participants self-select to participate within our programs. Teachers who self-select to participate in long-term professional development may have a higher motivation to utilize gains from internships within the classroom [11,22]. However, we cannot conclude that the outcomes were truly program-related or due to the talents of self-selected teachers who attend our program. Because this was not a randomized control trial, additional studies are needed to determine the RET impact on graduation and STEM major selection rates. One such study that we are currently conducting is an analysis of longitudinal student outcomes before a teacher participated in the program, during their year of the program, and the year following their participation in the RET using the RET participants as their own control may serve as a more direct indicator of program impact. We acknowledge that teachers grow and change each year; however, we plan to use the database to understand this growth in terms of their students' graduation rates and STEM major choices compared to non-RET participants.

Conclusion

The findings show students' high school graduation rates and undergraduate STEM major rates are higher when their teachers have participated in a RET program. Providing teachers with the opportunity to explore discovery science, connect with scientists and other STEM teachers, create lessons that use PjBL strategies and support throughout the year creates an ecosystem where teachers can enhance student interest in STEM studies. Furthermore, teachers who participate in the RET programs are more likely to teach using PjBL strategies and incorporate real-world engineering practices. It has shown that female and minority students are more likely to be influenced by these practices and seek careers utilizing these skills [7,10,15].

The above results present promising findings for the RET professional development programs. We note that we generated comparison samples via a statistical equating process and not a random assignment to groups. As such, results should be interpreted as associations with outcomes and not causal. In general, being instructed by RET teachers was associated with higher graduation rates and STEM major rates when compared to demographically similar students at the same campuses. We note

that these differences could be explained by an unobserved variable, exposure to PjBL from RET participants, or a combination of the two.

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