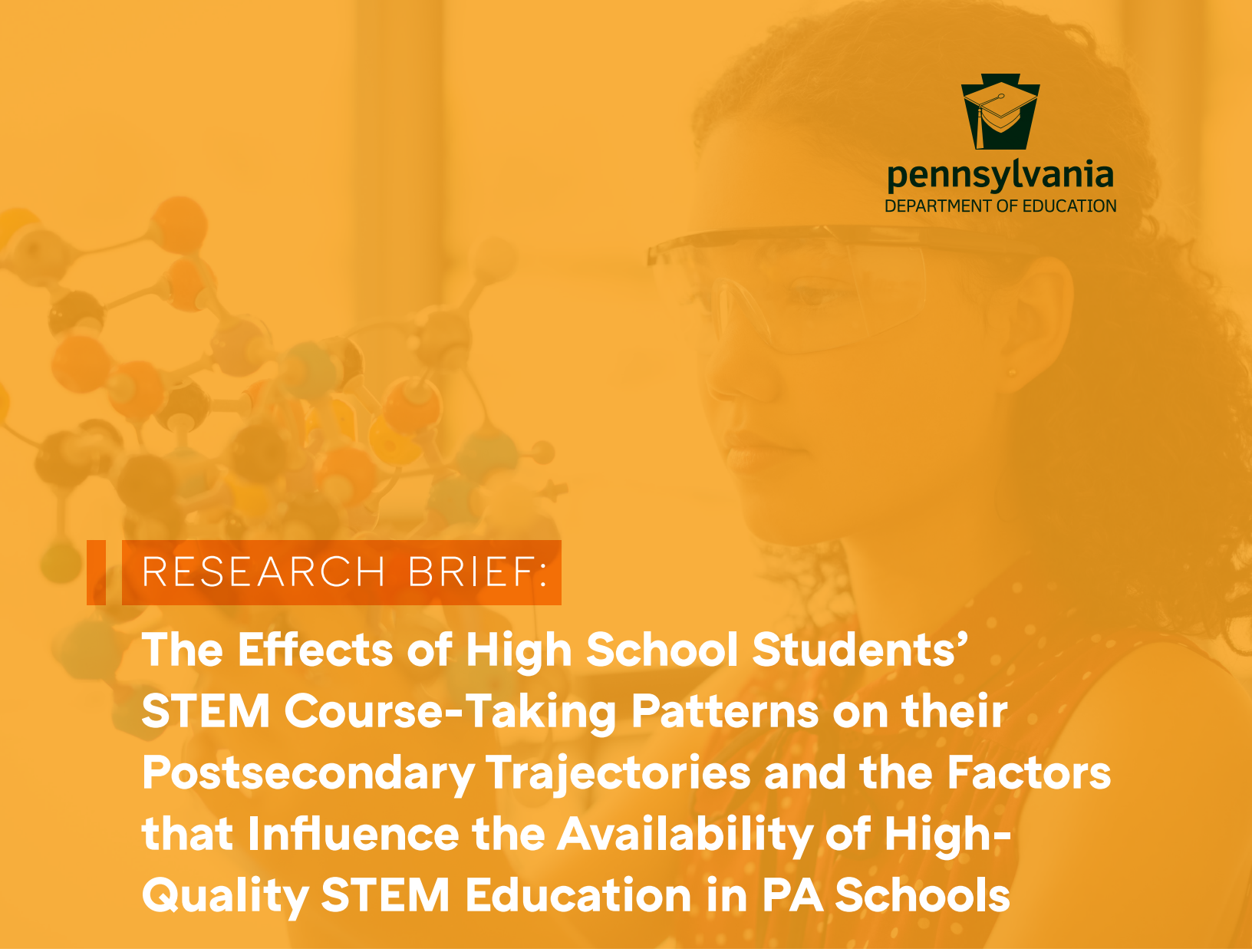

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RESEARCH BRIEF:

The Effects of High School Students' STEM Course-Taking Patterns on their Postsecondary Trajectories and the Factors that Influence the Availability of High-Quality STEM Education in PA Schools

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Research and Evaluation

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Abstract

In response to Pennsylvania's recent prioritization of STEM educational opportunities, the current study explored the relationship between high school STEM course-taking in PA and postsecondary outcomes, STEM course availability, and issues of STEM equity for various student demographics. Three cohorts of PA students (N = 340,738) were followed from Grade 9 entry to high school graduation; students were also followed to various points in postsecondary study, with one cohort followed to college graduation within four years of high school graduation. Findings showed that on average, students' likelihood of graduating high school, enrolling in college, graduating college within four years, and earning a STEM degree gradually increased as they enrolled in more STEM courses (especially rigorous and advanced STEM courses) during high school. Results also showed that while county-wide STEM workforce presence and the percentage of teachers with a graduate degree may be associated with advanced STEM course availability, higher STEM availability in PA schools did not necessarily result in higher STEM enrollment. Lastly, on average, results showed a disparity in STEM enrollment, availability, and STEM degree completion for several student demographic groups, including Black or African American, Hispanic, and historically underperforming students. However, women in PA enrolled in more rigorous/advanced STEM courses than men and were generally well-represented among STEM Bachelor's degree earners within four years of high school graduation. These findings are individually discussed through the lens of PA students.

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The Pennsylvania Department of Education (PDE) Evaluation and Research project is an effort that was established through a State Longitudinal Data System (SLDS) Grant from the Institute of Education Sciences (IES), National Center for Education Statistics (NCES), awarded in October 2015. The Research and Evaluation project is an initiative to make full use of the P-16+ system data and other data sources to answer priority questions from the PDE research agenda, to form collaborative research partnerships, and to increase PDE's capacity to conduct research. Our mission is to evaluate and analyze data to provide insight that can be used to positively impact policy, inform decision making and lead to improved student outcomes.

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Access the full report on "The Effects of High School Students' STEM Course-Taking Patterns on their Postsecondary Trajectories and the Factors that Influence the Availability of High-Quality STEM Education in PA Schools" **and additional Research Project reports on PDE's website.**

Project Overview and Objectives

The goal of the current research was to utilize data available for analysis on Pennsylvania students across time to examine the association between STEM course-taking patterns and postsecondary trajectories, as well as how teacher qualifications and STEM employment presence influence the availability of high-quality STEM education. Using statistical models that included a variety of potential indicators of high school and postsecondary outcomes, effects and variation in effects were estimated based on student demographics. This study had the following major objectives:

1. Identify the science, technology, engineering, and mathematics (STEM) course-taking patterns among high school students in PA

2. Connect STEM course-taking patterns to postsecondary trajectories, including college enrollment, persistence, retention, college graduation, and final major upon graduation

3. Investigate the relationship between STEM course availability and STEM enrollment to examine if PA students take advantage of available STEM courses

4. Determine if minority groups and women are significantly underrepresented in PA STEM education

5. Provide direction for future research and policy decisions aimed at increasing STEM availability and opportunities for postsecondary STEM education and employment

KEY FINDINGS:

STEM Course Enrollment

- For PA high school students in the three cohorts studied, higher STEM course enrollment was associated with positive academic outcomes, including on-time high school graduation, college enrollment, persistence, retention, and college graduation.

- Rigorous (AP, IB, or dual credit) and advanced (rigorous, gifted, or honors) STEM course enrollment during high school was strongly associated with college enrollment, moderately associated with college graduation, and strongly associated with earning a STEM degree upon graduation.

- While early enrollment (freshman or sophomore year) and late enrollment (junior or senior year) in advanced STEM courses were positively associated with favorable postsecondary outcomes in PA, late advanced STEM enrollment had the strongest association with college entry, persistence to year three of college, and college graduation.

- Enrollment in a strict measurement of STEM courses (only math, science, engineering, and technology) and a broader measure (including social and health sciences and architecture as well) were both associated with favorable educational outcomes for PA students.

- On average, PA females enrolled in rigorous and advanced STEM courses significantly more often than males; 56.2% of females participated in one or more advanced STEM courses, compared to 48.6% of males.

- On average, the percentage of White and Asian students who enrolled in one or more

These objectives reflect the two questions related to STEM education from the PDE Research Agenda, K – 12 Education Priority Area:

> *What is the impact of high school students' STEM course-taking patterns on their postsecondary trajectory? Do factors such as teacher qualifications/credentials and the presence of STEM employers in a region influence the availability of high-quality STEM education in PA?*

Literature Review

When Governor Wolf took office in 2015, Pennsylvania prioritized STEM (science, technology, engineering, and mathematics) educational opportunities to fill employment gaps and prepare PA learners for the future (Commonwealth of PA, 2019). However, the Education Commission of the States (ECS, 2019) has reported that PA industries are struggling to secure a qualified STEM workforce, a problem which may continue as PA STEM job opportunities are expected to grow by 8% through 2027. Now more than ever, it is essential to examine the health of the STEM ecosystem within PA to better understand how STEM opportunities may influence each other, whether they be in the high school classroom, on the college campus, or in the workforce.

Research has generally found that increased enrollment in high school STEM courses, especially advanced placement, dual credit, and honors STEM courses, is associated with choosing a STEM major and earning a STEM degree (Ackerman, Kanfer, and Calderwood, 2013; Shaw and Barbuti, 2010). Additionally, while several outlets have recommended prioritizing higher STEM course availability in schools (ACT, 2016; White House, 2017), few studies have investigated the nature of the association between STEM course availability and STEM course enrollment. Similarly, to the authors' knowledge, no study to date has examined how teacher qualifications and the presence of a

rigorous or advanced STEM courses was significantly higher than that of African American or Black and Hispanic students. Just over 16% of Black or African American and Hispanic students enrolled in one or more rigorous STEM courses, compared to 37% of White and 65% of Asian students.

- Logistic regression analysis results indicated that there was a statistically significant association between the number of rigorous and advanced STEM courses a student in PA takes throughout high school and on-time high school graduation and all postsecondary outcomes, even after holding all other explanatory variables constant. The odds of all favorable outcomes increased with each additional advanced STEM course taken.

KEY FINDINGS:

STEM Course Availability

- On average, students at PA schools that offered high amounts of STEM courses did not necessarily enroll in more STEM courses, but students who enrolled in more STEM courses generally had more available to them.
- Over half (56%) of Black or African American and 46% of historically underperforming high school students in PA were enrolled at schools that offered low amounts of STEM courses, compared to other schools in Pennsylvania.
- On average, the percentage of high school teachers in a county who have graduate degrees was found to be positively associated with rigorous and advanced STEM course availability in PA counties.
- For school year 2013-2014, in PA counties with low health science, social science, and architecture STEM employment, a higher percentage of teachers with graduate degrees was associated with higher advanced STEM availability and a lower percentage of teachers with graduate

regional STEM workforce might be linked to STEM course availability. Lastly, a relatively common finding in the STEM literature suggests that a disparity exists for various demographic groups, including women, African American, Hispanic, and historically underperforming students (Mulhere, 2015; Sass, 2015; U.S. Department of Education, 2016).

Method and Sample

Three cohorts of Pennsylvania students were followed from Grade 9 entry in school years 2010-2011, 2011-2012, and 2012-2013 to various points in postsecondary study depending on the cohort. Table 1 shows how each cohort was tracked through postsecondary enrollment and completion.

TABLE 1: Postsecondary Outcomes by 9th Grade Cohort

Outcome	Cohort 1 (2010-2011)	Cohort 2 (2011-2012)	Cohort 3 (2012-2013)
On-time High School Graduation	✓	✓	✓
College Entry	✓	✓	✓
Persistence & Retention to Year Two	✓	✓	✓
Persistence & Retention to Year Three	✓	✓	
College Graduation Within 4 Years	✓		
Retention to College Graduation	✓		
College Degree Type	✓		

The present study used pre-existing data, housed in various locations. Most of the student-centric data, including data on course enrollment and high school graduation, originated from a longitudinal data system called the Pennsylvania Information Management Systems (PIMS). Individual data templates from PIMS were combined to form full student cohort files. National Student Clearinghouse (NSC) data was used to track students' postsecondary trajectories, including college graduation and final major at graduation. Lastly, to assess PA's regional STEM workforce, occupational estimate data from the PA Department of Labor and Industry (DLI) examined the presence of individual STEM occupations within each PA county. Figure 1 displays the linking process for each individual data file or template, culminating

degrees was associated with lower advanced STEM availability. For counties in the same year with high health science, social science, and architecture STEM employment, this effect was not observed.

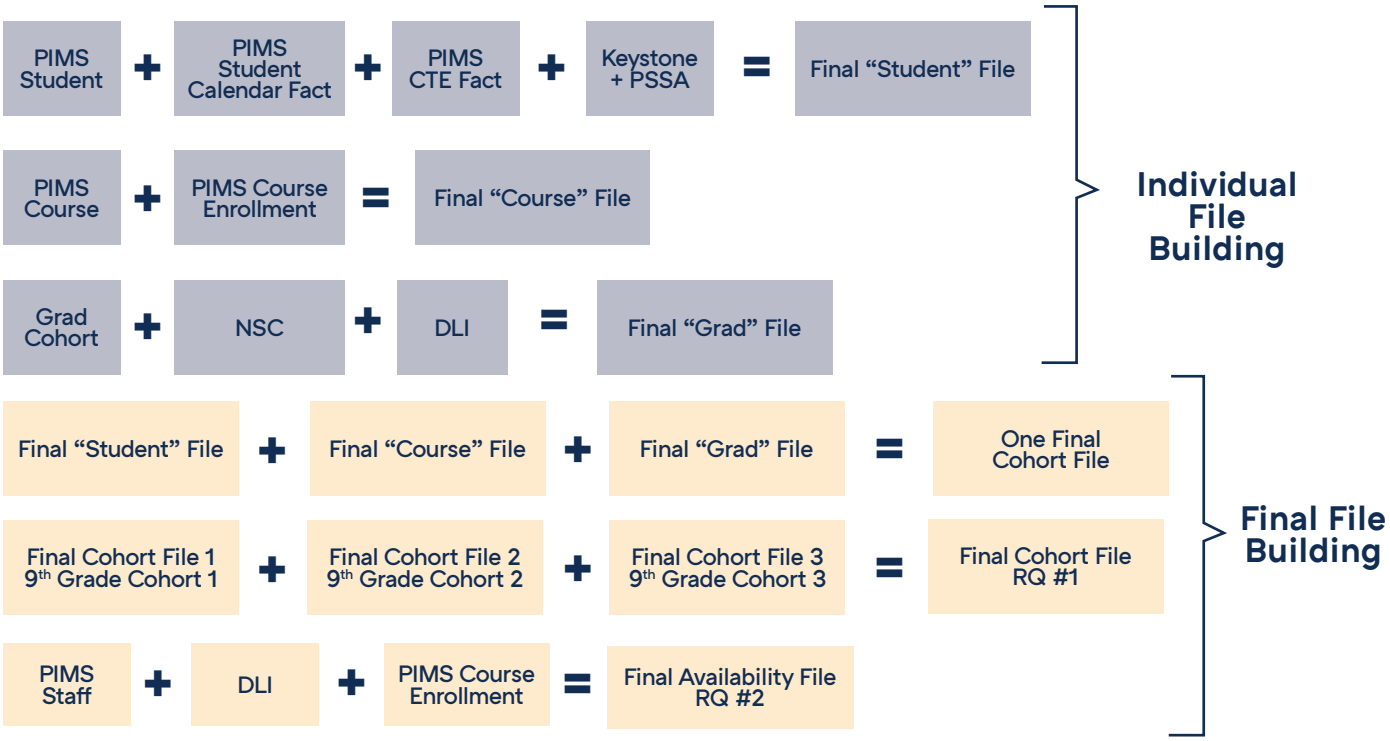
KEY FINDINGS:

STEM Degree Completion

- In PA high schools, higher STEM enrollment was moderately associated with earning a STEM and strict STEM college degree, and higher rigorous/advanced STEM enrollment was strongly associated with earning a STEM and strict STEM degree.
- Among college graduates, males (35%) were more likely to earn STEM degrees than females (18%); however, females were generally well-represented among all awarded STEM Bachelor's degrees, earning 45% compared to males at 55%.
- Only 13.5% of African American graduates earned a STEM degree, compared to 17.8% of Hispanics, 25.2% of Whites, and 42.4% of Asians. Only 14.5% of historically underperforming graduates earned STEM degrees, compared to 21% of non-historically underperforming students.

in final files to answer each research question. Lastly, varied statistical analyses were used, including descriptive statistics, Pearson and Linear-by-Linear Chi Squares, Analysis of Variance (ANOVA), Linear Regression, and Logistic Binary Regression.

FIGURE 1. Linking Process for Each Data File



Defining STEM

To accommodate various definitions of which subject areas should and should not be included under the STEM umbrella (U.S. Department of Commerce, 2011; U.S. Department of Homeland Security, 2016), the present study used several definitions of STEM for all measures (courses, occupations, and college majors). "Strict STEM" generally refers to a course, major, or occupation that heavily focuses on mathematics, life or physical sciences, technology, and engineering principles. References to "lenient STEM" include areas which are grounded in certain social sciences, health sciences, and architecture. Lastly, general references to "STEM" include topics which focus on the disciplines in strict STEM as well as those in lenient STEM, creating the most inclusive definition of STEM used in the present study. Comprehensive definitions for each can be found in Appendix A of the full report. It is worth nothing that the available data did not allow for study of STEM as an integrative discipline in which students receive holistic STEM instruction that crosses traditional subject-area boundaries (Sanders, 2012). Instead, for the present study, a measure was labeled as STEM according to its primary and individual area of focus.

The available data did not allow for study of STEM as an integrative discipline.

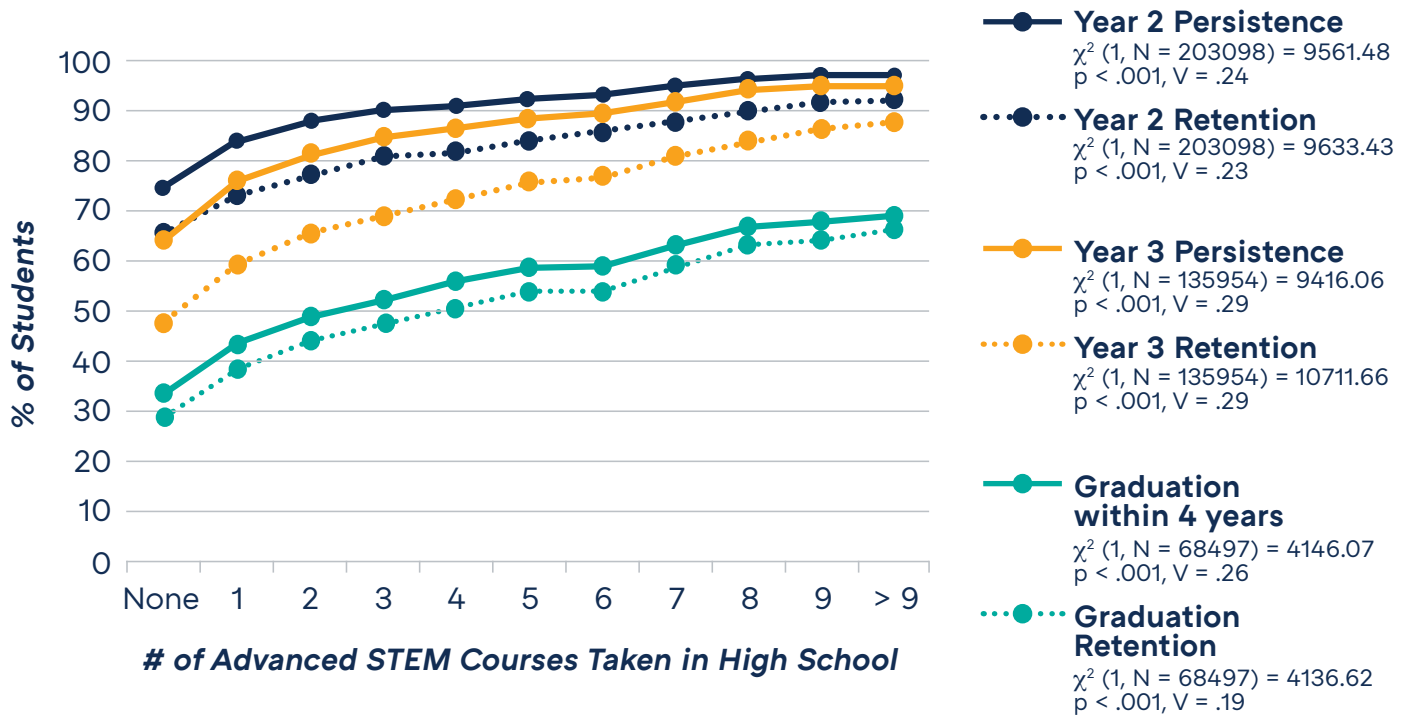
Discussion of Key Findings

Finding #1:

On average, higher STEM and rigorous/advanced STEM course enrollment was associated with high school graduation and positive postsecondary outcomes.

While STEM enrollment had a significant but small association with most outcomes (*V* = .032 to *V* = .151), rigorous and advanced STEM course enrollment was strongly associated with college enrollment (*V* = .312 and *V* = .367, respectively), and earning a STEM degree in college (*V* = .333 and *V* = .302, respectively), and was moderately associated with college graduation (*V* = .247 and *V* = .256, respectively). Figure 2 shows the relationship between advanced STEM enrollment in PA high schools and student postsecondary trajectories. These findings support previous literature which documented positive outcomes for students who enrolled in advanced STEM courses (Ackerman, Kanfer, and Calderwood, 2013; Shaw and Barbuti, 2010).

FIGURE 2. Postsecondary Outcomes by Number of Advanced STEM Courses Taken in High School



Finding #2:

Enrollment in both early and late timed advanced STEM courses was positively associated with favorable postsecondary outcomes.

Most of the previous literature on this topic has only examined timing of Algebra I (Clotfelter, Ladd, and Vigdor, 2015; U.S. Department of Education, 2018), which represents only a small portion of all STEM topics. The present study found positive associations between enrollment in early (taken during freshman or sophomore year) and late (taken during junior or senior year) timed advanced STEM courses and on-time high school graduation as well as all postsecondary outcomes. However, the strongest relationships were between late advanced STEM enrollment and college enrollment (V = .362), persistence and retention to year two (V = .237 and V = .227, respectively), and persistence and retention to year three (V = .292 and V = .285, respectively). It is possible that students' decisions to enroll in advanced STEM later in high school may be indicative of intentions to study at the college level.

Finding #3:

Students at schools that offered high numbers of STEM courses did not necessarily enroll in more STEM courses, but students with high STEM enrollment typically had more STEM courses available to them.

Results showed that on average, STEM enrollment in PA only varied by one course between schools that offered low numbers of STEM courses compared to schools that offered high amounts of STEM courses. This finding supports previous research which found that increasing STEM availability does not necessarily increase STEM enrollment and postsecondary outcomes on its own (Darolia, Koedel, Main, Ndashimye, & Yan, 2018). However, the present findings also showed that on average, students who enrolled in more STEM courses also tended to have more STEM courses available to them. These findings suggest that increasing STEM availability alone may not result in more STEM enrollment, but STEM enrollment may have the potential to influence STEM course availability in PA schools.

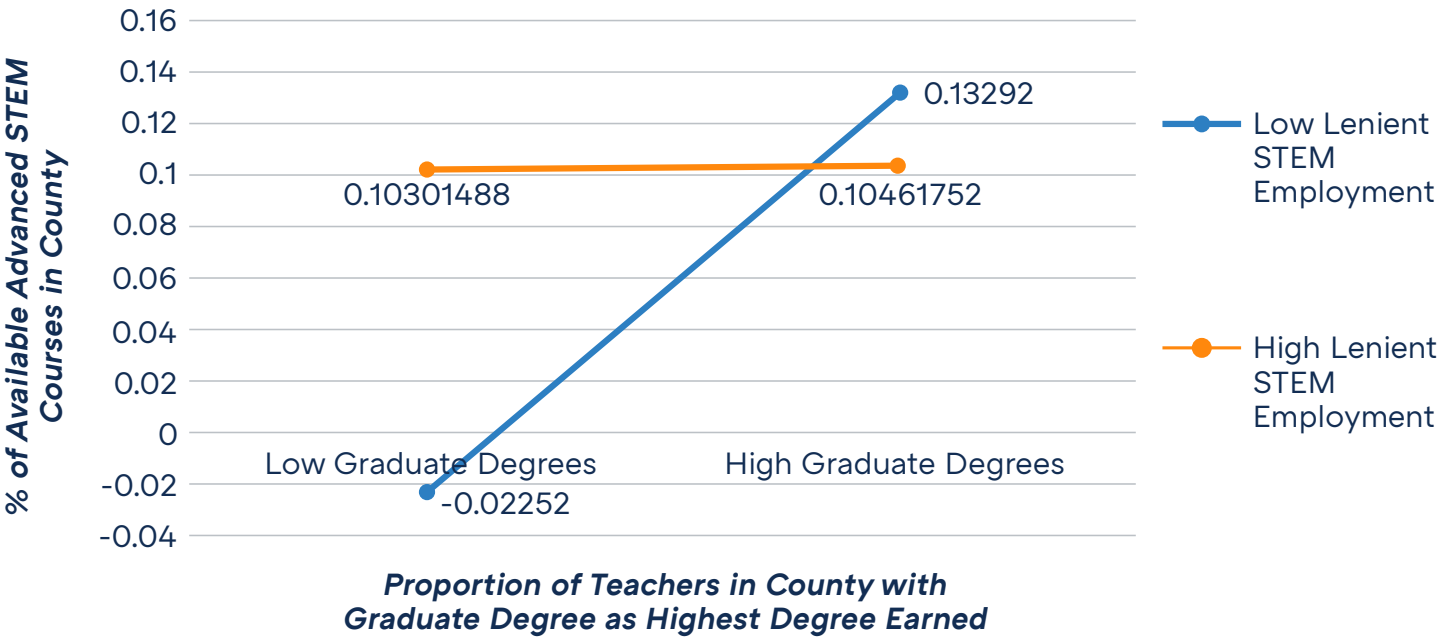
Finding #4:

A higher percentage of teachers with graduate degrees was associated with higher rigorous and advanced STEM availability in PA counties.

Results showed that a higher percentage of teachers with graduate degrees in PA counties was positively associated with advanced STEM availability for all school years (2013-2014, 2014-2015, and 2015-2016) and rigorous STEM availability for school years 2013-2014 and 2014-2015. Also, for school year 2013-2014, the percentage of teachers with graduate degrees varied with county-wide lenient STEM employment presence (jobs focusing on health sciences, social sciences, and architecture) and the interaction

between these two variables was found to be associated with 34% of the variance in advanced STEM availability. As Figure 3 shows, in counties with high lenient STEM employment, the percentage of teachers with graduate degrees did not meaningfully impact advanced STEM course availability. However, in counties with low lenient STEM employment, counties with a higher percentage of teachers with graduate degrees tended to have higher advanced STEM availability, while counties with a lower percentage of teachers with graduate degrees tended to have lower advanced STEM availability. These results suggest that many factors, including teacher and STEM workforce characteristics, may influence STEM course availability in schools.

FIGURE 3. Association between Lenient STEM Employment and Teacher Degree Type on the Availability of Advanced STEM Courses in 2013-2014



Note. Regression Equation: % Available Advanced STEM Courses in County 2013-2014 = -.066 + .262 * GRAD + 1.46 * LENIENT – 2.126 * (GRAD * LENIENT)

Finding #5:

For some outcomes, there is unequal representation in STEM education for several demographic groups in PA.

Results showed that Black or African American, Hispanic, and historically underperforming students (special education, EL, or economically disadvantaged) enrolled in rigorous and advanced STEM courses and graduated with STEM degrees at lower rates than their White peers. Additionally, more than half of Black or African American students were enrolled at schools with low STEM availability. These

outcomes were similar for historically underperforming students. However, females enrolled in rigorous and advanced STEM courses more often than males. Additionally, although a higher percentage of male college graduates earned STEM degrees compared to female graduates, females were relatively well represented among STEM degree earners, receiving 45% of STEM Bachelor's degrees.

Conclusion

To compete in a world where science and innovation drive economies, Pennsylvania and the United States must prioritize high-quality STEM opportunities at all areas in the STEM pipeline. The current research suggests that STEM enrollment in high school may have far-reaching positive effects on students' postsecondary outcomes. While increasing STEM course availability may not significantly influence STEM enrollment, results suggest a complex relationship between the two variables which warrants further study. Issues of equity in STEM continue to be of paramount importance, as engaging underrepresented minority groups in STEM serves to strengthen the local and nation-wide STEM economy. While STEM engagement for all groups is essential, the current study finds that the simple act of enrolling in STEM courses during high school is associated with a positive, meaningful, and long-lasting influence on a child's education.

The simple act of enrolling in STEM courses during high school is associated with a positive, meaningful, and long-lasting influence on a child's education, including postsecondary outcomes.

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