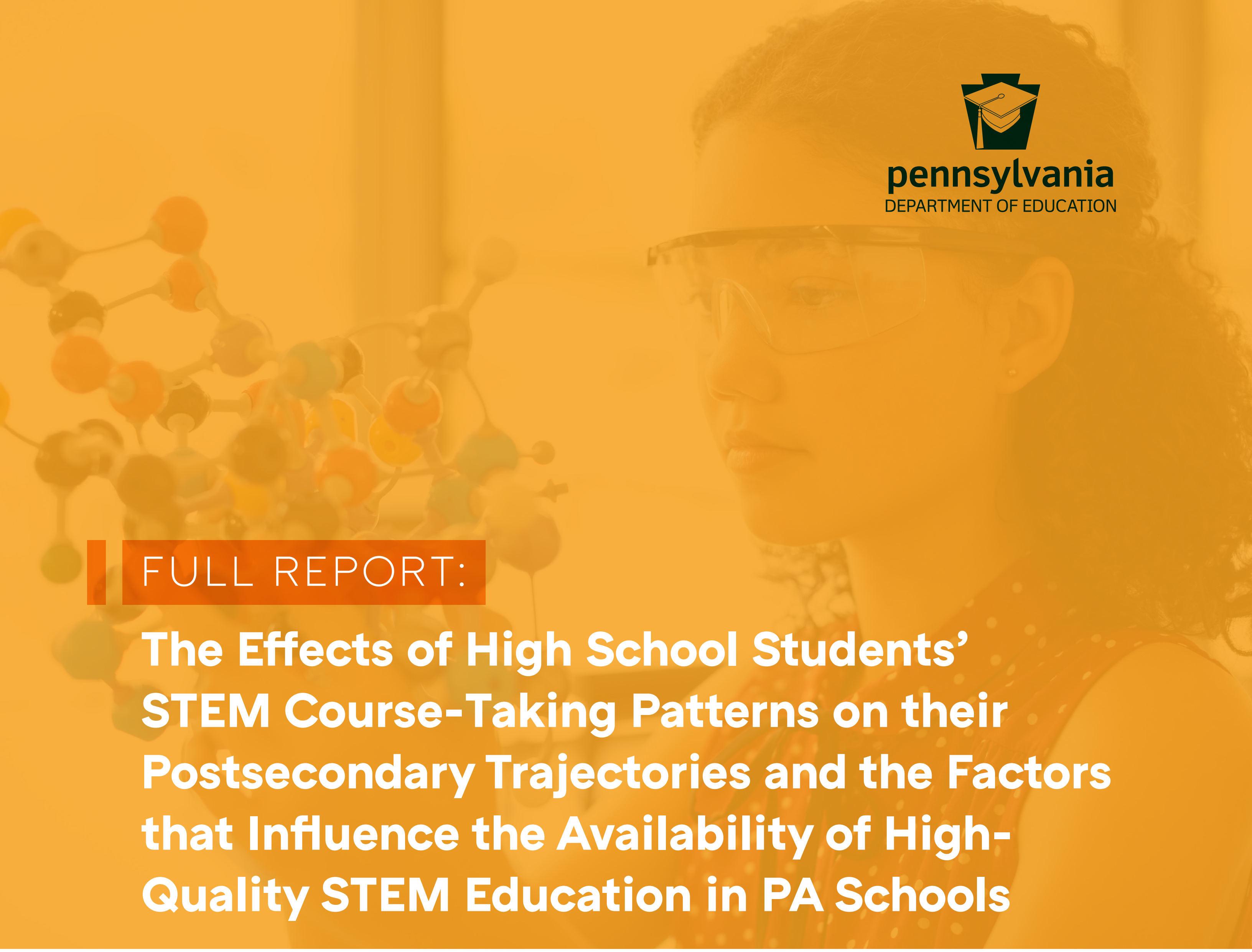

FULL REPORT:

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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DEPARTMENT OF EDUCATION
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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Introduction

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. To this end, the Wolf Administration recently allocated $70 million to improve STEM education and workplace training in PA (Commonwealth of Pennsylvania, 2019). Despite this focus on increasing the availability and quality of STEM opportunities, the Education Commission of the States (ECS, 2019) 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 landscape 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.

The present study has several major objectives. To describe how STEM education is linked to various outcomes, it is essential to identify and describe the STEM course-taking patterns among high school students in PA. Next, to assess the importance of STEM in high school, STEM course-taking will be connected to students' postsecondary trajectories, such as graduation and final major. Third, the relationship between high school course availability and course enrollment will be described to examine if students take advantage of available STEM opportunities. Fourth, teacher qualifications and regional STEM employer presence will be assessed and potentially linked with the availability of high-quality STEM in PA. Finally, equity in STEM opportunities will be addressed to determine if various minority groups are underrepresented in STEM courses and majors in Pennsylvania.

"The simple act of enrolling in STEM and advanced STEM courses during high school may have a positive, meaningful, and long-lasting influence on the education of children in Pennsylvania.

The Effects of STEM Course-Taking in High School

Often discussed, the concept of the "STEM pipeline" refers to the passage of STEM learners from their earliest days of education to secondary and postsecondary learning opportunities, eventually culminating when STEM learners join the STEM workforce (Sass, 2015). Many have emphasized the importance of early student engagement in STEM topics (Master, Cheryon, Moscatelli, & Meltzoff, 2017; Tyler-Wood, Ellison, Lim, & Periathiruvadi, 2012), but a variety of researchers have focused on STEM education in high school, as this is generally the first time students exert some control over their own course-taking.

Regarding the decision to major in a STEM field, Wang (2013) documented that high school science and math enrollment is strongly associated with the decision to pursue a STEM degree. Additionally, Maltese and Tai (2010) found that the number of completed science courses during high school was positively associated with earning a STEM degree in college. Speaking to the importance of rigorous course-taking, studies have also found that students who enrolled in advanced placement (AP) STEM courses were more likely to persist in STEM throughout college than students who did not enroll in AP STEM courses (Ackerman, Kanfer, & Calderwood, 2013; Shaw & Barbuti, 2010). However, LeBeau et al. (2012) found no significant association between specific high school course-taking and college graduation with a STEM degree. Although more research is needed, findings suggest that high school STEM course-taking is positively linked to pursuing and persisting with a STEM major during college.

STEM Enrollment Timing

When examining performance data of students around the world, American students typically fall in the middle ranks when measuring math and science performance (Pew Research Center, 2017). One proposed method to increase long-term student performance is to expose students to various STEM courses, specifically algebra, at an earlier age. The U.S. Department of Education (2018) reported that the 25% of American students who enroll in Algebra I during eighth grade are more prepared for later STEM enrollment than their peers who enroll in Algebra I at a later time. However, Clotfelter, Ladd, and Vigdor (2015) found that early enrollment in Algebra I may be associated with beneficial outcomes for high-achieving students but may result in negative outcomes for other students.

While Algebra I is only a small part of overall STEM course-taking, comparatively few researchers have studied how timing of enrollment in other STEM courses is related to student success. Most research on early exposure to STEM has focused on early and middle childhood (McClure et al., 2017; Tippett & Milford, 2017), seemingly ignoring how exposure to advanced STEM courses during the early years of high school may positively influence student outcomes. This potential relationship may show that students who enroll in advanced STEM courses early in high school have better outcomes than students who enroll in late advanced STEM courses, or vice versa.

Access to STEM and Rigorous STEM Courses

President Obama's "STEM for All" initiative proposed a three-pronged approach to improve nation-wide STEM opportunities for American students. Focusing on STEM teacher quality and equal representation in STEM opportunities, the campaign also highlighted the need for ubiquitous access to advanced STEM courses in high school (White House, 2016). In support of this priority, American College Testing (ACT, 2017) reported that access to and enrollment in advanced science classes in high school is linked to higher preparedness for college study. However, in a comprehensive study on math and science high school course access, Darolia, Koedel, Main, Ndashimye, and Yan (2018) failed to find any significant associations between STEM course offerings and postsecondary STEM outcomes, such as earning a STEM degree. Further, results from Wang (2013) suggested that increasing STEM access alone is not associated with increased STEM postsecondary aspirations. Instead, several researchers have proposed that efforts to increase STEM enrollment, in addition to STEM course offerings, will produce the most observable gains in postsecondary STEM outcomes (Garland & Rapaport, 2017; Thomas, Singh, Klopfenstein, & Henry, 2013).

In 2016, the U.S. Department of Education, Office of Civil Rights reported that only 50% and 63% of American high schools offered calculus and physics, respectively (Department of Education, 2016). Many researchers have also found that underrepresented minority (URM) groups have less access to STEM courses. Specifically, studies have reported that schools with high percentages of URM students tended to offer less rigorous courses than schools with lower percentages of URM students (Bernard-Brak, McGaha-Garnett, & Burley 2011; Pretlow & Wathington, 2003). On the other hand, Garland and Rappaport (2017) found that in Texas high schools, as representation of Hispanic and Black/African American students increased, access to advanced STEM courses also increased. More research is needed to determine how access to advanced STEM courses varies by demographic status, and if differential STEM access is related to student outcomes.

The Importance of STEM Instructors – Teacher Qualifications and Student Outcomes

In late 2018, the U.S. Department of Education announced that it had eclipsed President Trump's call for STEM educational investment by allocating $279 million to secure high-quality STEM teachers around the country (U.S. Department of Education, 2018). Responding to this call to action, Pennsylvania launched its K-12 STEM Educator Toolkit, a website designed as an interactive platform where PA teachers can upload lessons, activities, and other STEM based curricula to share with other teachers (Commonwealth of Pennsylvania, 2018). While the United States and Pennsylvania have been taking steps to increase the quality of available STEM education, researchers have been studying how teachers' qualifications, including their highest degree and years of experience, influence their students' outcomes.

While teachers with master's degrees can usually expect to earn a higher salary than their counterparts with Bachelor's degrees (National Council on Teacher Quality, 2018), the impact of holding a master's degree on student performance is questionable. In North Carolina, Ladd and Sorensen (2015) found no significant effect for teachers with master's degrees on student performance but did note that higher rates of teachers with master's degrees were associated with lower student absenteeism. Similarly, Winters (2011) and Chingos and Peterson (2011) reported that the number of teachers with advanced degrees was not significantly associated with student performance. However, results from Zhang (2008) disagreed with this conclusion, finding that teachers who held master's degrees in science positively influenced student science performance. More research is needed to determine if any association exists between advanced teacher education and student outcomes.

Researchers also look to teachers' years of experience as a measure of quality. Hightower et al. (2011) and Goe and Stickler (2008) reported that teacher experience is associated with student achievement during a teacher's first few years in the classroom, but the effect dissipates as the teacher becomes more experienced. In terms of STEM education, Lichtenberger and George-Jackson (2013) found that teacher degree level did not boost student STEM interest, but higher teacher experience was significantly associated with higher student STEM interest. Additionally, Henry, Fortner, and Bastian (2012) found that the experience levels of high school math and science teachers were positively related to student performance. While research has generally found that teacher qualifications are not directly related to student achievement, they may subtly influence how students perceive STEM topics and perform in STEM courses.

STEM Equity – STEM Course Enrollment and Earning a STEM Degree

The Pennsylvania Department of Education (PDE, 2019) believes that all students have the potential to succeed and benefit from a STEM education. However, research in PA and beyond has focused on studying differences in STEM-related outcomes between population demographics. Specifically, many studies have prioritized documenting and explaining differences in STEM outcomes between males and females as well as various racial and ethnic groups. Outcomes often studied in terms of equity include STEM high school course enrollment and college graduation with a STEM major.

A common finding in STEM equity research suggests that the pipeline can be especially “leaky” for girls and certain racial and ethnic minorities, including African American and Hispanic students (Mulhere, 2015; Sass, 2015). Because these demographic groups constitute over half of Pennsylvania’s workforce (ECS, 2019), it is essential to understand why they are not equally represented in STEM opportunities when comparted to their White male counterparts.

STEM course-taking patterns and performance in high school are frequently compared between various groups. Kahn and Ginther (2018) reviewed literature and concluded that girls enroll in less science and engineering courses than boys, but female AP STEM enrollment varies by STEM sub-topic; girls enroll in fewer advanced computer science, math, and math-heavy sciences (e.g., physics), but enroll in more AP courses in environmental sciences and biology than boys. However, research reviewed by Lichtenberger and George-Jackson (2013) found that girls and boys complete similar amounts of math and science advanced placement (AP) courses in high school.

To address potential disparities between racial and ethnic groups for high school STEM enrollment, the U.S. Department of Education (2016) reported average percentages of school enrollment versus course enrollment for various student groups. Results showed that while African American students were 16% of all enrolled high school students, they represented only 8% of all students enrolled in calculus. Meaningful disparities for African American students were also reported for physics enrollment. Similarly, Hispanic students comprised 24% of all enrolled students but only 16% of those enrolled in calculus. Taken together, these results suggest that there may be a significant enrollment gap in STEM courses for girls and various URM groups.

If there is a disparity in STEM course enrollment for women and URM groups, it is possible that college graduation rates for STEM majors also differ by demographic groups. The National Science Foundation (NSF, 2014) and the National Center for Education Statistics (NCES, 2019) reported this very effect. While girls earn a higher percentage of all Bachelor’s degrees than boys do, boys earn substantially more STEM Bachelor’s degrees (64%) than girls (36%) (NCES, 2019). Further, while White students make up 56% of the population aged 18-24, they earn 63% of the nation’s science and engineering Bachelor’s degrees. Black or African American and Hispanic students constitute 15% and 20.5% of the population aged 18-24, but only earn 8.8% and 10.3% of the nation’s science and engineering degrees, respectively. Together, research focused on equity in STEM opportunities has generally discovered disparities for women and URM groups for STEM high school course enrollment and STEM college graduation rates.

The STEM Workforce

In addition to producing a more STEM-literate citizenry, the purpose of increasing STEM access, performance, and college graduation rates is to prepare and maintain a high-quality STEM workforce. Various governmental agencies have stated that a well-qualified STEM workforce is the key to maintaining economic competitiveness and ensuring the prosperity of the country (Bureau of Labor Statistics, 2014; Department of Homeland Security, 2018). Additionally, many outlets point to unequal representation among demographic groups, especially women and racial/ethnic minorities, as a weakness of the current STEM landscape (Charleston, Adserias, Lang, & Jackson, 2014; National Science Board, 2018). Further, to the authors' knowledge, no study to date has examined how STEM course availability is related to a local or regional STEM workforce presence. This potential association may highlight how various points of the STEM pipeline are connected, from STEM in the classroom to STEM job opportunities after graduation.

Main and Secondary Research Questions

Considering the previous literature, the current study seeks to answer the following research questions, including two main research questions and five additional sub-questions.

Main Research Questions:

1. Are STEM course-taking patterns in high school associated with postsecondary trajectory, as defined by college enrollment, persistence and retention through college, and college graduation?
2. Are teacher qualifications/credentials (years of teaching experience and highest degree) and the presence of STEM employment in PA counties associated with the availability of high-quality STEM education in PA schools?

Additional Sub-Research Questions:

1. What is the description and breakdown of student cohort populations by year?
2. Are postsecondary trajectories differentially affected by advanced STEM courses taken early in high school as opposed to later in high school?
3. Are factors related to STEM education and STEM employment availability in a student's county associated with his or her college major upon graduation?
4. How is STEM and strict STEM course availability related to STEM and strict STEM course enrollment during high school?
5. Are minority groups significantly underrepresented in STEM opportunities in PA?

Method

Participants

Three cohorts of Pennsylvania students were followed from Grade 9 entry for the present study. The first cohort was followed from school year 2010-2011 until on-time college graduation in school year 2017-2018. The second cohort was followed from Grade 9 entry in 2011-2012 until their third year of college in 2017-2018. Lastly, the third student cohort was followed from Grade 9 entry in 2012-2013 until their second year in college during school year 2017-2018. A reduced data file was created to address questions related to STEM enrollment; this file contained only students who had records found for all four years of high school enrollment. This was to prevent comparisons between students who had all four years of course data and students who may have only had enrollment records for two or three years. However, for research questions unrelated to STEM course enrollment, the complete file was used which contained all students who entered Grade 9 in school year 2010-2011, 2011-2012, or 2012-2013. All students in each cohort attended a public Pennsylvania local educational agency (LEA), Intermediate Unit (IU), public charter school, or public cyber charter school. For a full demographic breakdown of all participants included in both full and reduced cohort files, refer to Appendices B and C.

Procedures and Data File Preparation

The present study used pre-existing data, housed in various locations. Research questions were addressed through the analysis of linked Pennsylvania Information Management Systems (PIMS) datasets, National Student Clearinghouse (NSC) records, and occupational estimates for each PA county provided by the PA Department of Labor and Industry (DLI). For the three cohorts studied, PIMS data were obtained for school years 2010-2011 through 2015-2016, while NSC records were obtained through 2017-2018 for PA high school graduates from school years 2014, 2015, and 2016. Lastly, DLI data was obtained for each year a 9th grade cohort graduated from high school (2014, 2015, and 2016) to estimate workforce conditions when high school graduates were selecting a college major or entering the workforce.

Five PIMS Templates were used to gather demographic and descriptive data of the sample. The PIMS Student Template was used to report student-level demographic data, including gender, race/ethnicity, special education status, English learner (EL) status, and others. The Student Calendar Fact Template provided student enrollment information, such as days enrolled in a district and days present in school. The CTE Student Fact Template described vital information specific to Career and Technology Education students, such as gender, race/ethnicity, status as a rigorous CTE student, and indicators describing a CTE student's internship or work experiences. Fourth, the PIMS Staff Template was used to measure PA teacher demographic information, including teacher gender, race/ethnicity, years of teaching experience, and highest earned degree. Each teacher was assigned to a PA county according to the location of their primary school district. Teacher demographic data was then aggregated to determine county-wide teacher characteristics. Lastly, Grad Cohort data files compiled by PDE described the status of each year's graduating high school class, including demographic information.

To analyze STEM course-taking patterns in high school, two PIMS data templates were required. The PIMS Course Template provided detailed information on each course offered across LEAs in PA, including the course's code and numerical designation, subject area, rigorous/advanced status, and other important information. When linked with the PIMS Student Course Enrollment Template by school year, the researchers were able to obtain course-taking information for each student across school years. To track this information, a STEM or non-STEM designation process was implemented for each course. Each course was also labelled as rigorous or non-rigorous, advanced or non-advanced, and algebra or non-algebra. Information on the definitions of these categories and processes can be found in Appendix A.

After each course was properly labelled, grand totals for each student were created to assess how many courses of each category students enrolled in during high school. Dichotomous variables were also created to indicate whether a student participated in at least one course of a particular category (STEM, rigor, etc.). Lastly, variables indicating the timing of various types of courses were created. For the cohorts used in the present study, a student was considered to have early timing for a class if she or he was enrolled during their 9th or 10th grade year; subsequently, late timing included enrollment during the 11th or 12th grade year. To supplement course enrollment data, performance scores from the Pennsylvania Keystone standardized exams were also used. PDE (2019) describes the Keystone tests as end-of-course exams which measure ability in various subject areas, including algebra, literature and English, life sciences, and others. Scaled scores were used, as well as a dichotomous indicator of overall achievement level reflecting advanced/proficient and basic/below basic.

Two main data sources were used to determine high school graduation status and postsecondary trajectory. The Graduation Cohort data files provided high school graduation records, including an indicator for four or five-year high school graduation. The occupational workforce data, as described below, were linked to the Graduation Cohort data files for a later merge with the student and course data files. This allowed specific questions related to high school course-taking and graduation to be addressed. National Student Clearinghouse (NSC) data was used to track students' postsecondary trajectories after high school graduation. The NSC data reported student records for college enrollment, institution type (2-year versus 4-year), institution sector (public/private), enrollment status (part versus full-time), graduation status, the major and degree type a student graduated with, and other information related to a student's postsecondary tenure. College majors were coded as either STEM or non-STEM based on guidelines set by the Department of Homeland Security. More information on this coding process can be found in Appendix A. NSC files were matched with Grad Cohort data files based on high school graduation year.

The final data source was provided by the PA Department of Labor and Industry (DLI). Three files, describing county-wide occupational estimates for years 2014 through 2016, were used to estimate students' regional STEM workforce presence at high school graduation. In the data's original form, each county's total occupational workforce was broken down by individual occupations including STEM jobs (statistician, engineer) and non-STEM jobs (lawyers, retail). Each occupation was designated as STEM or non-STEM by the researchers based on various definitions by U.S. governmental departments; more information on this process can be found in Appendix A. At this point, all STEM occupations by type were totaled for each county; afterwards, a percentage for each category was calculated to determine a county's STEM workforce compared to their total workforce, and so on.

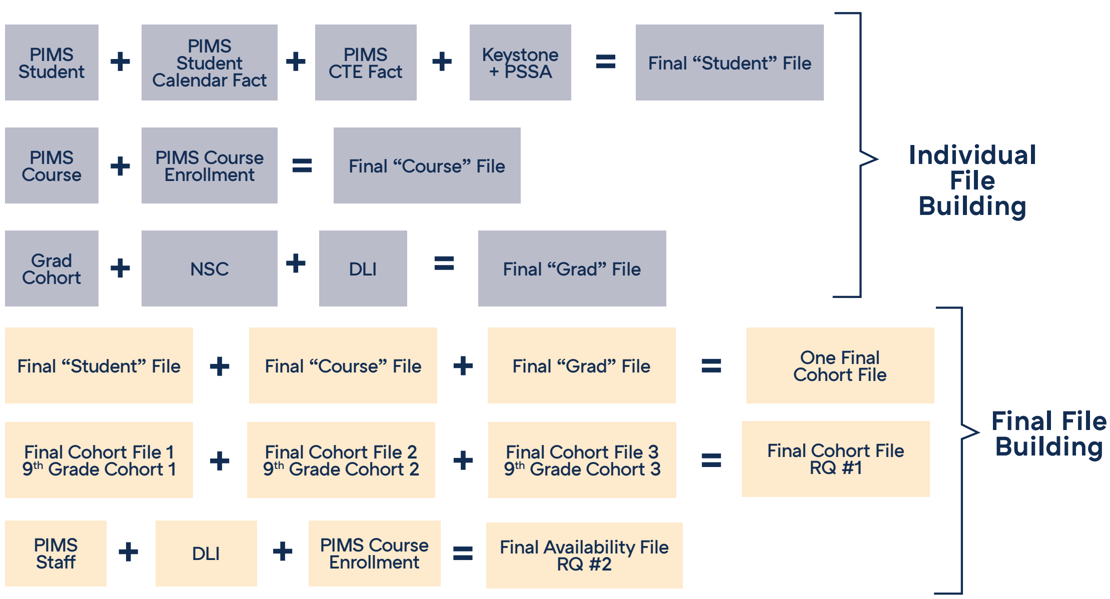
The linkage process for the above datasets, in chronological order, can be found in Figure 1. The PIMS Student Template was linked to the PIMS Student Calendar Fact to observe student characteristics, including demographic and enrollment information. This combined file was then merged with the PIMS CTE Student Fact Template, centrally locating all student-level descriptive information. Next, the PIMS Course Template was linked with the PIMS Course Enrollment Template to obtain detailed course enrollment records for each student in all cohorts. At this time, the file containing all student-level descriptive data was linked to the file containing all course and course-enrollment information. Next, Keystone data were linked only for the third 9th grade cohort, as reporting of this information did not become mandatory until the 2014-2015 school year. This process formed the final file used for analysis for main research question #1, sub-research questions #1-3, and sub-question #5.

A separate process was used to create the file used to answer main research question #2 and sub-question #4. Because the DLI data were aggregated at the county level, all other variables which could potentially interact with STEM employer presence were also aggregated at the county level. First, the PIMS Staff Template and the DLI occupational data were linked by county. Then, the PIMS Course Enrollment files were reduced so that only records for each unique course, identified by LEA specific course code, remained. Special education courses and students were not included in availability analyses, as special education courses are not accessible to most students. Totals of unique courses by sub-type (STEM, advanced STEM, etc.) were created for each LEA, then aggregated to the county-level. The full, final file contained records at the county level for teacher qualifications and credentials, DLI occupational workforce estimates, and course availability.

After these steps were completed, three cohort files were built to represent each 9th grade cohort. Students who entered Grade 9 during the 2010-2011 school year were included in the first cohort file, students who entered Grade 9 in 2011-2012 made up the second file, and students who entered Grade 9 in 2012-2013 comprised the final 9th grade cohort file. Each cohort file was then linked to the corresponding NSC data to match the cohort's high school graduation year. Lastly, all three 9th grade cohort datasets were combined to obtain one file with the final sample.

A separate file linking procedure was implemented to answer main research question #2. Using the PIMS Course and Course Enrollment Templates, rigorous and advanced STEM availability was calculated at the county level using steps highlighted in Appendix A. This data was linked to the PIMS Staff data and the DLI occupational data (also aggregated by county).

FIGURE 1. Linking Process for all Data Files



These data were analyzed using varied analytic methods that included descriptive statistics, Analysis of Variance (ANOVA), Chi-Square (Pearson and Linear-by-Linear), and Linear and Logistic Regression analysis. Results are disaggregated and differentiated by student groups that are of interest to state policymakers, including ethnicity, socioeconomic status, gender, EL status, and Special Education. The analyses were exploratory in nature, which allowed examination of several individual variables that could be associated with high school and postsecondary outcomes. In the first phase of analysis, student population characteristics were examined descriptively to explore patterns, variable distributions, and the raw differences in outcomes associated with each independent variable individually. In the second phase of analysis, Logistic Regression was used to explore the cumulative effects of variables associated with the highest amount of explained variance in the final statistically significant model.

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). While specific information regarding these classifications can be found in Appendix A, “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 jobs, courses, or majors which are grounded in the social sciences (typically psychology, economics, sociology, etc.), health sciences, and architecture. Lastly, general references to “STEM” include courses, college majors, or jobs 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. It is worth noting 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 course, college major, or occupation was labelled as STEM according to its primary, individual area of focus.

Results

Sub-Question #1:
What is the description and breakdown of student cohort populations by year?

All three student cohorts were individually examined to explore potential differences in demographic factors and course-taking behaviors. Appendix B shows that the breakdown of student population by demographic was similar across the three cohorts. There were 140,299 total students in the first cohort; 51.4% were male and 48.6% were female. Fifteen percent identified as Black or African American, 8.2% were Hispanic, 72% were White, 1.3% were multi-racial, 3.2% were Asian, and a combined 2% identified as American Indian/Alaskan Native or Native Hawaiian or Pacific Islander. Further, 44.8% of students were part of the historically underperforming student group, meaning they were a special education student, an English Learner, or economically disadvantaged. Just over 2% of students were EL, 14.3% were special education students, and 37.7% were economically disadvantaged.

In total, 139,071 students comprised the second cohort. Of these students, 50.8% were male and 49.2% were female. Ethnic and racial composition showed Black or African American students were 15.4% of the cohort, Hispanic students were 8.8%, White students were 70.7%, multi-racial students were 1.5%, and American Indian/Alaskan Native and Native Hawaiian or Pacific Islander students were 2% of the sample. Lastly, a total of 46.3% of students were considered historically underperforming, breaking down to 2.2% as EL, 15% as special education, and 39.3% as economically disadvantaged.

The third and final student cohort was composed of 138,971 students, 51.3% of whom were male and 48.7% female. The racial/ethnic group breakdown was similar to the previous cohorts, with 15.2% identifying as African American, 9.2% as Hispanic, 70% as White, 1.8% as multi-racial, 3.5% as Asian and 3% as either American Indian/Alaskan Native or Native Hawaiian or Pacific Islander. Among these students, 46.6% were historically underperforming, 2.4% were EL, 15.4% were special education students, and 39.6% were economically disadvantaged.

For variables related to STEM course-taking patterns, only students with all four years of course records were included in analyses. This was to prevent comparisons between students who had all four years of course records and students who may have only had two or three years of information. When students without all four years of course data were excluded, a total of 115,068 students remained in the first cohort, 113,170 in the second, and 112,520 students remained in the third cohort. Appendix C provides a descriptive breakdown of student demographic characteristics after this file reduction. As the table shows, the student group percentages are similar to those reported for all cohorts in Appendix B for the full population of students. However, comparisons between full and reduced cohorts showed a small reduction in representation for African American students (from over 15% to over 12% representation) and for Hispanic students (from 8-9% to 6-7%). However, the ethnic/racial breakdown in the reduced file closely mirrors PA census information from 2010 which found that roughly 12% of PA citizens are African American and 7.6% identify as Hispanic (U.S. Census Bureau, 2010.)

Enrollment in rigorous STEM courses varied by racial and ethnic group but remained relatively static across the three cohorts. For rigorous STEM enrollment, results showed that 16.3% of African American students and 16.2% of Hispanic students participated in one or more rigorous STEM course. Comparatively, 36.8% of White students and 64.9% of Asian students participated in rigorous STEM courses. For enrollment in rigorous strict STEM, 13.7% of Black or African American students and 13.8% of Hispanic students enrolled in one or more course, compared to 31.9% of White students and 59.6% of Asian students. Lastly, for advanced STEM course enrollment, 38% of Hispanic and African American students participated in at least one course compared to 55% of White students and almost 80% of Asian students. The differences between proportions were statistically significant for rigorous STEM enrollment (χ^2(1, N =340,758) = 12,576.27, p < .001), rigorous strict STEM enrollment (χ^2(1, N = 340,758) = 11,669.89, p < .001), and advanced STEM enrollment (χ^2(1, N = 340,758) = 9,274.11, p < .001). The associations between race/ethnicity and rigorous STEM/rigorous strict STEM enrollment were moderate (V = .210, V = .200, respectively) but the association between ethnicity and advanced STEM enrollment was small (V = .165). For information related to how STEM course enrollment varies by cohort, refer to Appendices D through F.

Main Research Question #1:
Are STEM course-taking patterns in high school associated with postsecondary trajectory, as defined by college enrollment, persistence, retention, and graduation within four years?

Descriptive Breakdown of Postsecondary Outcomes

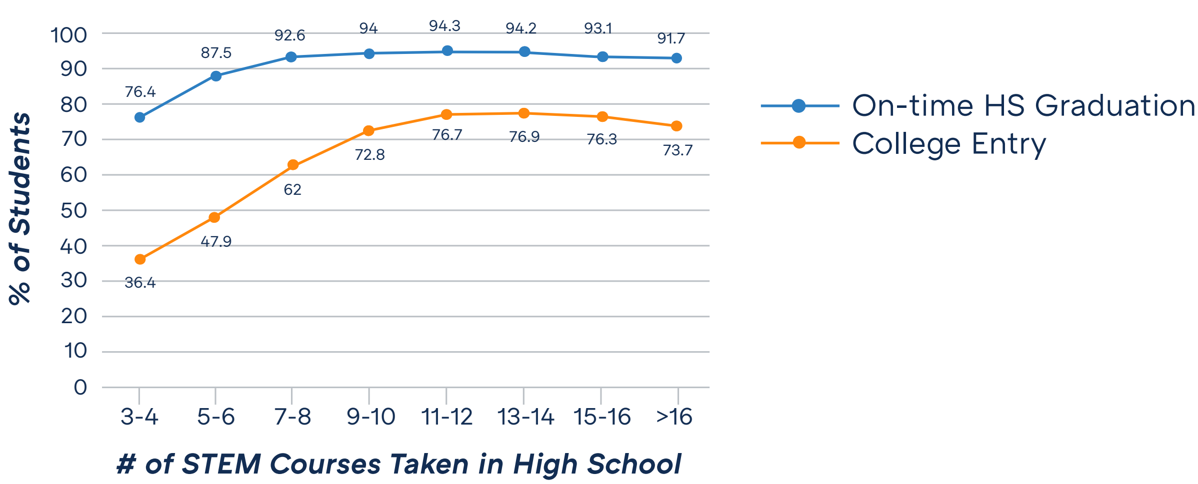
For students with all years of course data, descriptive information of relevant outcome variables are as follows. Ninety-three percent of students graduated high school on-time within four years and 72.3% of these high school graduates enrolled in postsecondary education. For students who entered in the fall or prior, 74.7% of students enrolled at 4-year institutions, while 21% enrolled at 2-year institutions. Of all students who enrolled at any postsecondary institution in the fall or prior immediately after high school graduation, 85.5% returned to a college for their second year (persisted) and 76.5% returned to the same college for their second year (retention). Of these students, 78.6% returned to a college for their third year, while 64.1% of students stayed at the same institution. Out of all students followed who enrolled in college and were followed to on-time college graduation (9th grade cohort #1 only), 47.5% graduated within four years after high school graduation and 90% of those graduates did so from the same college where they were initially enrolled. Of the 47.5% of students who graduated, 13% graduated with an Associate's degree (AA) and 80.2% graduated with a Bachelor's degree or higher (BD). However, for all students who entered a postsecondary institution, 6.2% graduated with an AA and 38.1% graduated with a BD or higher within 4 years.

STEM Course Enrollment

On-time high school graduation and postsecondary enrollment. Figure 2 shows the association between the number of STEM courses a student enrolls in during high school and on-time high school graduation and postsecondary enrollment. An overwhelming majority of students enrolled in at least one or more STEM courses in high school (approximately 99%). Therefore, Figure 2 only represents the percentages for students who took more than two STEM courses, because the total number of students who took fewer than three courses is very small (n = 424).

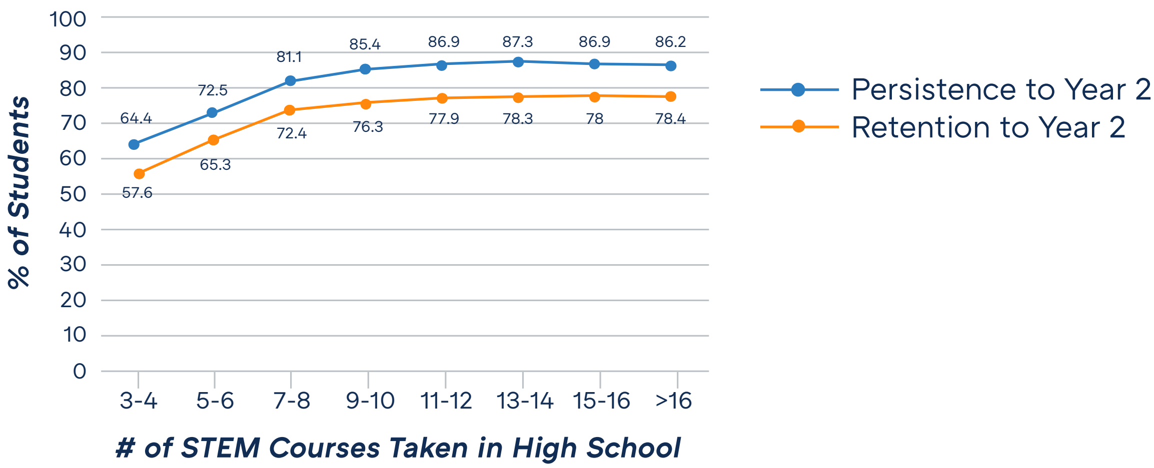
The effect of STEM course-taking is greater for postsecondary enrollment than on-time high school graduation. For on-time high school graduation, there was an increase from 76.4% for students who enrolled in three or four STEM courses to 87.5% for students who enrolled in five or six STEM courses. As Figure 1 shows, the effect for on-time high school graduation peaked at student enrollment in 11 or 12 STEM courses, with 94.3% graduating from high school on-time. For postsecondary enrollment, there is a continual rise from 36.4% with enrollment in three or four STEM courses to 72.8% with enrollment in nine or ten STEM courses, peaking at 76.9% for enrollment in 13 to 14 STEM courses. The difference in proportions was significant for both on-time high school graduation ($\chi^2(1, N = 340{,}738) = 476.78$, $p < .001$) and postsecondary enrollment ($\chi^2(1, N = 315{,}143) = 4{,}219$, $p < .001$), but the associations were small ($V = .106$ and $V = .151$, respectively).

FIGURE 2: On-time High School Graduation and Postsecondary Entry by STEM Courses Taken in High School



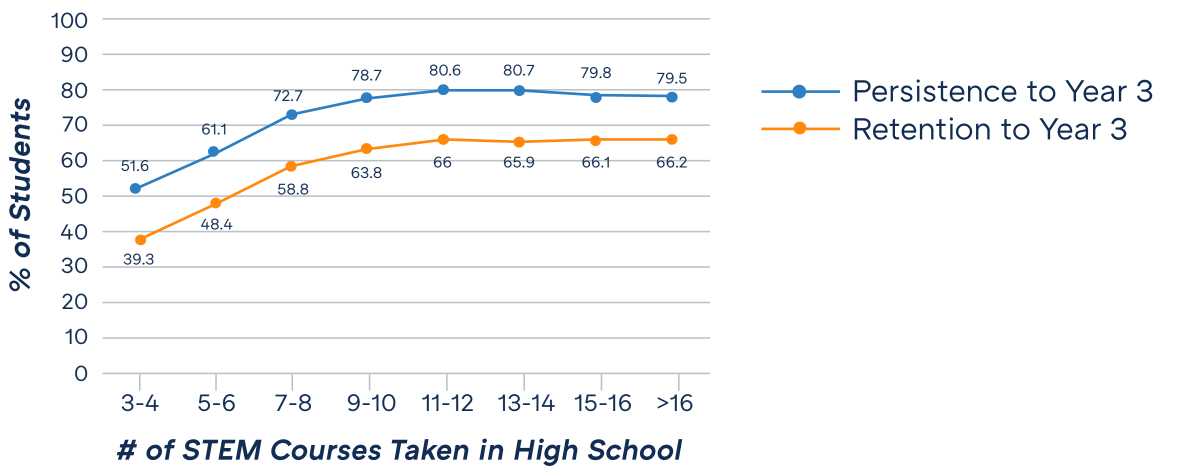
Persistence and retention to year two of postsecondary. Figure 3 reflects the relationship between high school STEM enrollment and persistence and retention to year two of college study. The effect of STEM course-taking was larger for persistence than for retention to year two. For persistence to year two, there was an increase from 64.4% for students who enrolled in three to four STEM courses to 72.5% for those who enrolled in five or six courses, peaking at 87.3% for students who enrolled in 13 or 14 STEM courses. For retention to year two, there was a continual rise from 57.6% for those who enrolled in three or four STEM courses to 65.3% for those who participated in five or six, peaking at 78.4% for those who enrolled in more than 16 STEM courses. The difference between proportions was significant for both persistence to year two ($\chi^2(1, N = 203{,}098) = 590.3, p < .001$) and for retention to year two ($\chi^2(1, N = 203{,}098) = 401.4, p < .001$), but the associations were very small ($V = .074$ and $V = .057$, respectively).

FIGURE 3: Persistence and Retention to Second Year by Number of STEM Courses Taken in High School



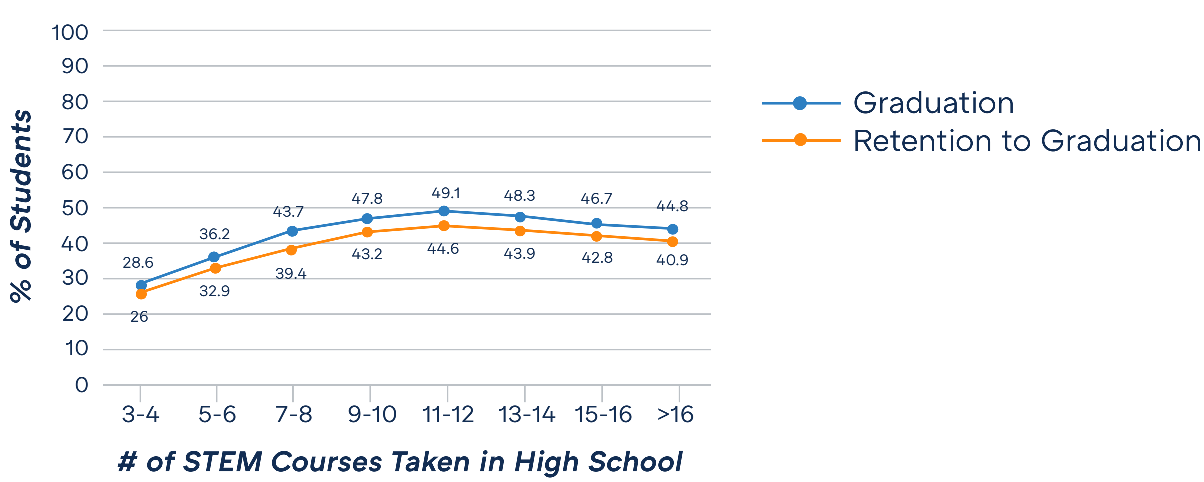
Persistence and Retention to year three of postsecondary. Figure 4 displays the association between STEM course enrollment and persistence and retention to year three of college. Again, the relationship between STEM course enrollment was stronger for persistence to year three than retention to year three. For persistence to year three, there was an increase from 51.6% for students who enrolled in three or four STEM courses to 61.1% for those who enrolled in five or six, peaking at 80.7% for those who enrolled in 13 or 14 STEM courses. For retention to year three, there was a gradual increase from 39.3% for students who enrolled in three or four STEM courses to 48.4 % for those who enrolled in five or six, peaking at 66.2% for students who enrolled in more than 16 STEM courses. The difference between proportions was significant for both persistence to year three ($\chi^2(1, N = 135{,}954) = 452.58, p < .001$) and for retention to year three ($\chi^2(1, N = 135{,}954) = 332.96, p < .001$), but the associations were both small ($V = .083$ and $V = .065$, respectively).

FIGURE 4: Persistence and Retention to Third Year by Number of STEM Courses Taken in High School



Graduation within four years and retention to college graduation. In addition to persistence and retention through college, Figure 5 shows the relationship between high school STEM enrollment and graduation within four years and retention to college graduation. The effect of STEM enrollment was larger for college graduation within four years than for retention. For college graduation, there was an increase from 28.6% for those who enrolled in three or four STEM courses to 36.2% for those who participated in five or six, peaking at 49.1% for those who enrolled in 11 or 12 STEM courses. For retention to graduation, Figure 5 shows a gradual increase from 26% for those who enrolled in three or four STEM courses to 32.9% for those who took five or six, peaking at 44.6% for those who enrolled in 11 or 12 STEM courses. There was a statistically significant difference between proportions for graduation within four years ($\chi^2(1, N = 68{,}497) = 29.9$, $p < .001$) and for retention to graduation ($\chi^2(1, N = 68{,}497) = 29.82$, $p < .001$). However, both associations were small ($V = .044$ and $V = .032$, respectively).

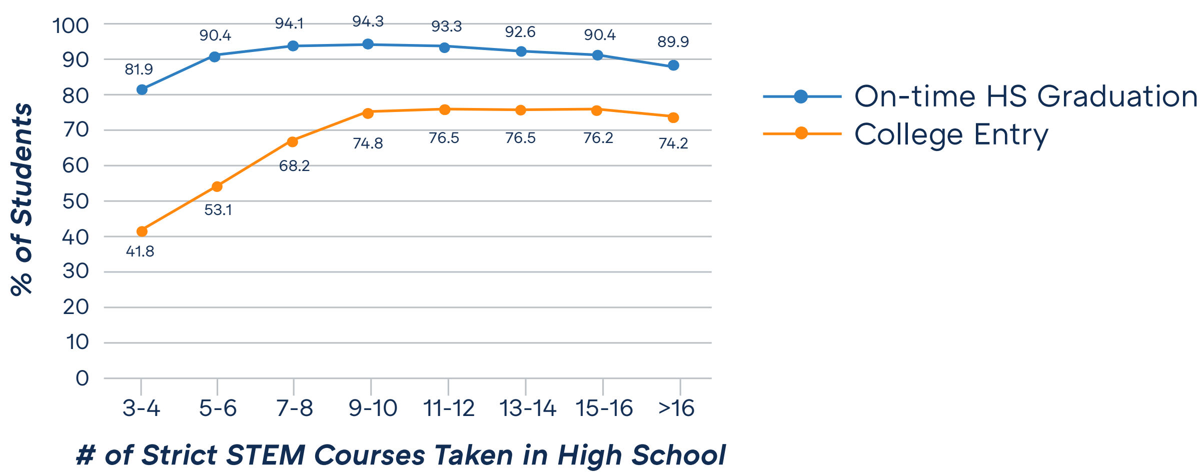
FIGURE 5: Graduation within Four Years and Retention to College Graduation by Number of STEM Courses Taken in High School



Strict STEM Course Enrollment

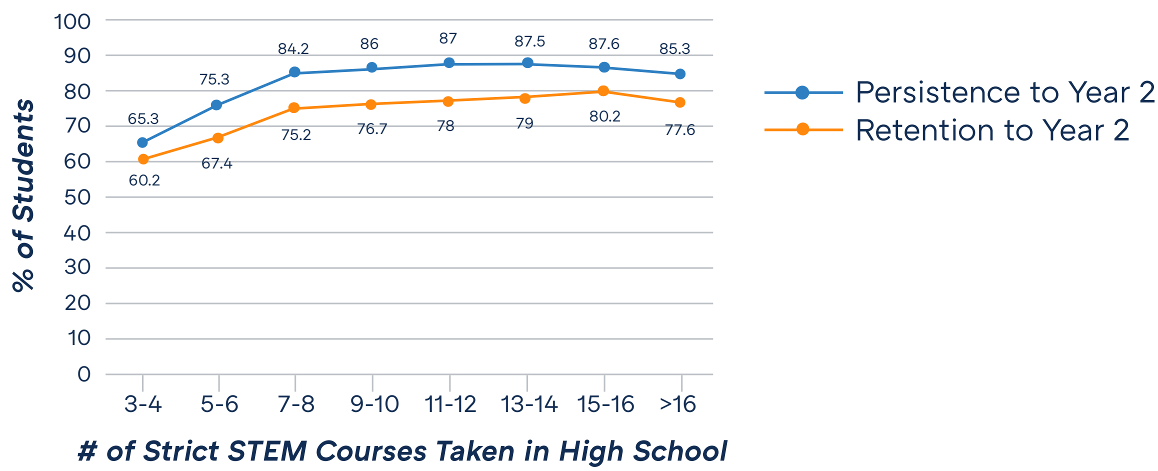
On-time high school graduation and college enrollment. Figure 6 displays the association between enrollment in strict STEM courses during high school and on-time high school graduation and college enrollment. The relationship between strict STEM course-taking and college enrollment was stronger than strict STEM enrollment and high school graduation. For high school graduation, there was a steady increase from 81.9% for those who enrolled in three or four strict STEM courses to 90.4% for those who enrolled in five or six strict STEM courses, peaking at 94.3% for students who enrolled in nine or ten strict STEM courses. For college enrollment, there was a gradual increase from 41.8% for students who enrolled in three or four strict STEM courses to 53.1 % for those who enrolled in five or six strict STEM courses, eventually peaking at 76.5 % for students who participated in 11 or 12 strict STEM courses. The difference between proportions was significant for both on-time high school graduation ($\chi^2(1, N = 340{,}738) = 10.17$, $p < .001$) and for college enrollment ($\chi^2(1, N = 315{,}143) = 3{,}254.36$, $p < .001$), although the associations were both small ($V = .101$ and $V = .132$, respectively).

FIGURE 6: On-time High School Graduation and Postsecondary Entry by Strict STEM Courses Taken in High School



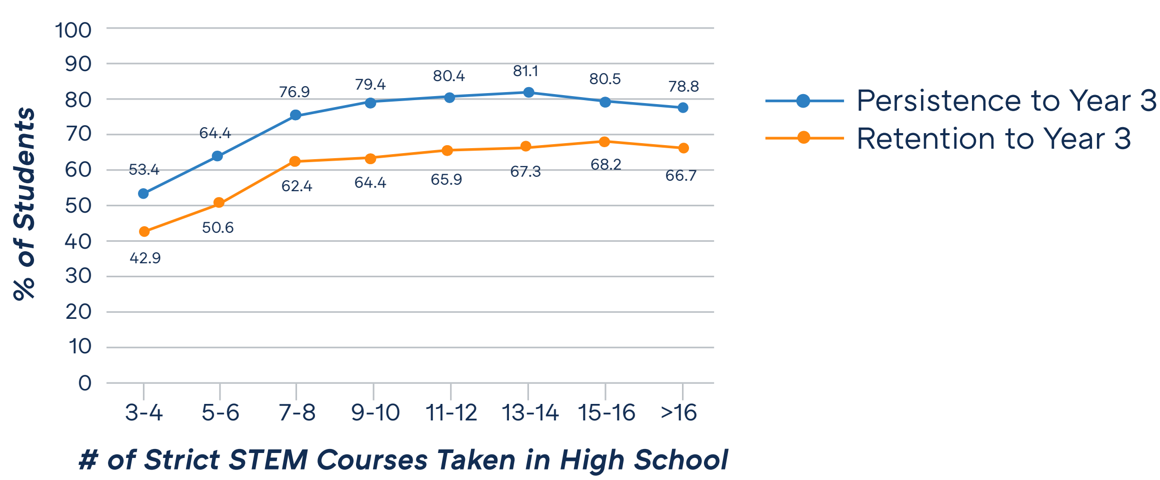
Persistence and retention to year two of postsecondary. Figure 7 displays the relationship between strict STEM course-taking in high school and persistence and retention to year two of college. The association between strict STEM course-taking and persistence to year two was stronger than strict STEM enrollment and retention to year two. For persistence to year two, there was a steady increase from 65.3% for students who enrolled in three or four strict STEM courses to 75.3% for students who participated in five or six strict STEM courses, peaking at 87.6% for students who enrolled in 15 or 16 strict STEM courses. Figure 7 shows that for retention to year two, there was a gradual increase from 60.2% for students who participated in three or four strict STEM courses to 67.4% for those who enrolled in five or six strict STEM courses, peaking at 80.2% for students who participated in 15 or 16 strict STEM courses. The difference between proportions was significant for both persistence to year two ($\chi^2(1, N = 203{,}098) = 469.37$, $p < .001$) and for retention to year two ($\chi^2(1, N = 203{,}098) = 366.37$, $p < .001$), but both associations were very small ($V = .067$ and $V = .052$, respectively).

FIGURE 7: Persistence and Retention to Second Year by Number of Strict STEM Courses Taken in High School



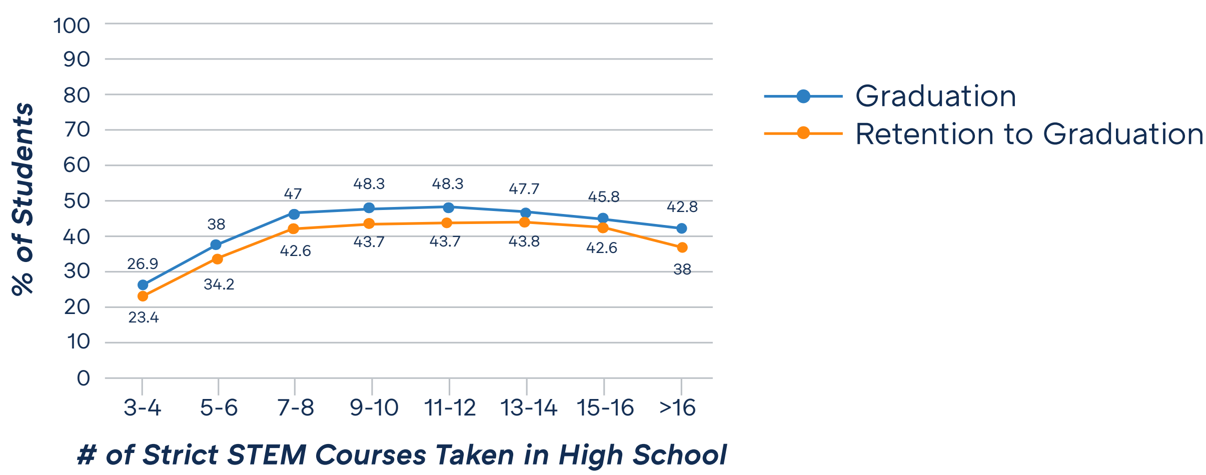
Persistence and retention to year three of postsecondary. Figure 8 shows the relationship between strict STEM course enrollment and persistence and retention to year three of college. The relationship between strict STEM enrollment and persistence to year three was stronger than strict STEM enrollment and retention to year three. For persistence to year three, there was a gradual increase from 53.4% for those who enrolled in three or four strict STEM courses to 64.4% for those who participated in five or six strict STEM courses, peaking at 81.1% for those who enrolled in 13 or 14 strict STEM courses. Figure 8 shows that for retention to year three, there was a steady increase from 42.9% for those who enrolled in three or four strict STEM courses to 50.6% for students who enrolled in five or six strict STEM courses, peaking at 68.2% for those who participated in 15 or 16 strict STEM courses. The differences between proportions were significant for both persistence to year three ($\chi^2(1, N = 135{,}954) = 379.81$, $p < .001$) and for retention to year three ($\chi^2(1, N = 135{,}954) = 340.61$, $p < .001$); however, both associations were small ($V = .077$ and $V = .064$, respectively).

FIGURE 8: Persistence and Retention to Third Year by Number of Strict STEM Courses Taken in High School



Graduation within four years and retention to on-time college graduation. Figure 9 shows the relationship between strict STEM course enrollment and graduation within four years and retention to college graduation. The relationship between strict STEM enrollment and graduation within four years is stronger than strict STEM enrollment and retention to graduation. For graduation, there was a gradual increase from 26.9% for students who enrolled in three or four strict STEM courses to 38% for students who participated in five or six strict STEM courses, peaking at 48.3% for those who enrolled in nine or ten strict STEM courses. For retention to graduation, there was a steady increase from 23.4% for students who took three or four strict STEM courses to 34.2% for those who enrolled in five or six, peaking at 43.8% for those who participated in 13 or 14 strict STEM courses. Figure 9 shows that the difference between proportions was significant for graduation within four years ($\chi^2(1, N = 68{,}497) = 14.52, p < .001$) and for retention to graduation ($\chi^2(1, N = 68{,}497) = 14.47, p < .001$), although both associations were small ($V = .042$ and $V = .031$, respectively).

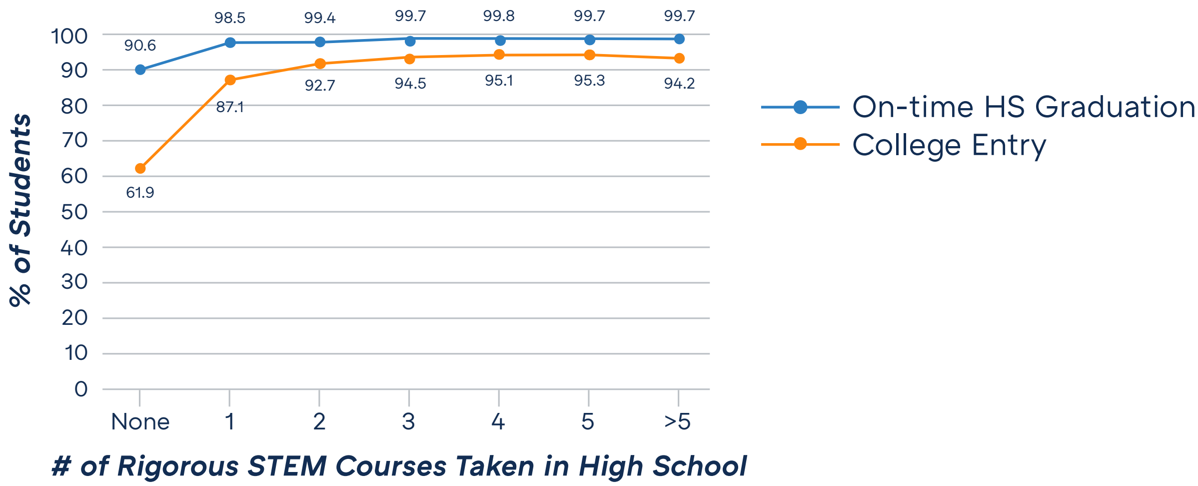
FIGURE 9: Graduation within Four Years and Retention to College Graduation by Number of Strict STEM Courses Taken in High School



Rigorous STEM Course Enrollment

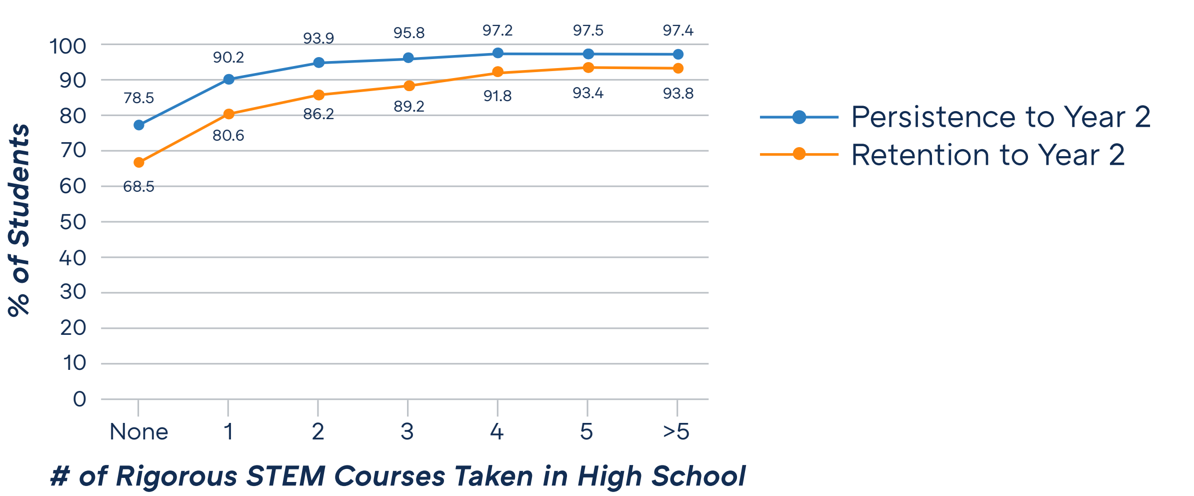
On-time high school graduation and college enrollment. Figure 10 indicates the relationship between rigorous STEM enrollment, on-time high school graduation, and college enrollment. The relationship between rigorous STEM enrollment and college enrollment is stronger than rigorous STEM enrollment and high school graduation. For high school graduation, there was a steady increase from 90.6%. for students who did not enroll in any rigorous STEM to 98.5% for students who participated in just one rigorous STEM course, peaking at 99.8% for students who enrolled in four rigorous STEM courses. For college enrollment, there was also a gradual increase from 61.9% for students who did not participate in rigorous STEM to 87.1% for students who enrolled in one rigorous STEM course, peaking at 95.3% for those who enrolled in five rigorous STEM courses. The differences between proportions were significant for both on-time high school graduation ($\chi^2(1, N = 340{,}738) = 6{,}109.75, p < .001$) and for college enrollment ($\chi^2(1, N = 315{,}143) = 22{,}118.77, p < .001$). The association between rigorous STEM course-taking and high school graduation was small ($V = .163$), but the relationship between rigorous STEM participation and college enrollment was strong ($V = .312$).

FIGURE 10: On-time High School Graduation and Postsecondary Entry by Rigorous STEM Courses Taken in High School



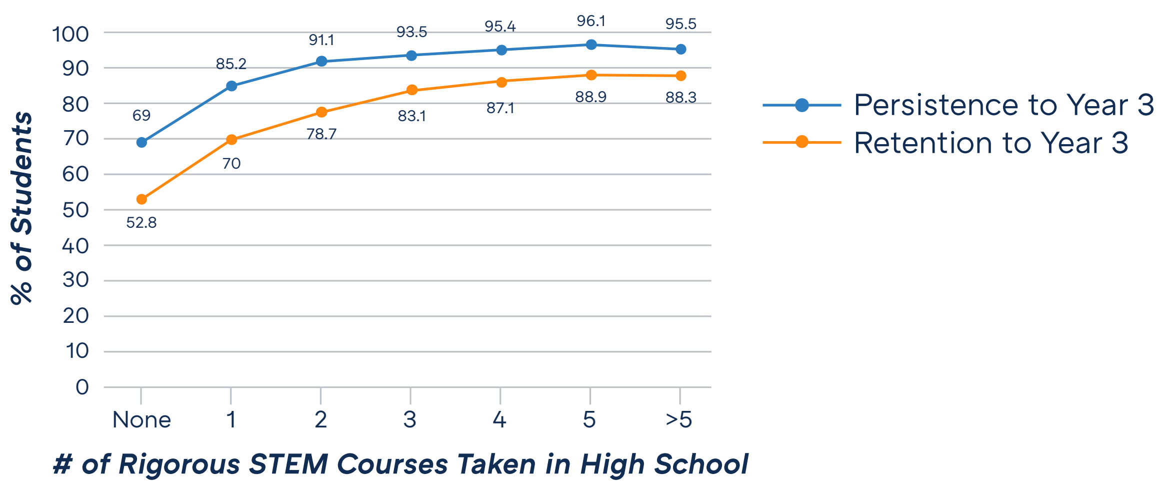
Persistence and retention to year two of postsecondary. Figure 11 refers to the relationship between rigorous STEM enrollment and persistence and retention to year two of college. The association between rigorous STEM enrollment and persistence to year two was stronger than rigorous STEM enrollment and retention to year two. For persistence to year two, there was a gradual increase from 78.5% for students who did not participate in rigorous STEM to 90.2% for students who enrolled in just one rigorous STEM course, peaking at 97.5% for students who enrolled in five rigorous STEM courses. For retention to year two, there was also a steady increase from 68.5% for students who did not enroll in rigorous STEM to 80.6% for students who participated in one rigorous STEM course, peaking at 93.8% for students who enrolled in more than five rigorous STEM courses. The difference between proportions was significant for persistence to year two ($\chi^2(1, N = 203{,}098) = 7{,}403.18$, $p < .001$) and for retention to year two ($\chi^2(1, N = 203{,}098) = 7{,}931.25$, $p < .001$) and both associations were moderate ($V = .216$ and $V = .213$, respectively).

FIGURE 11: Persistence and Retention to Second Year by Number of Rigorous STEM Courses Taken in High School



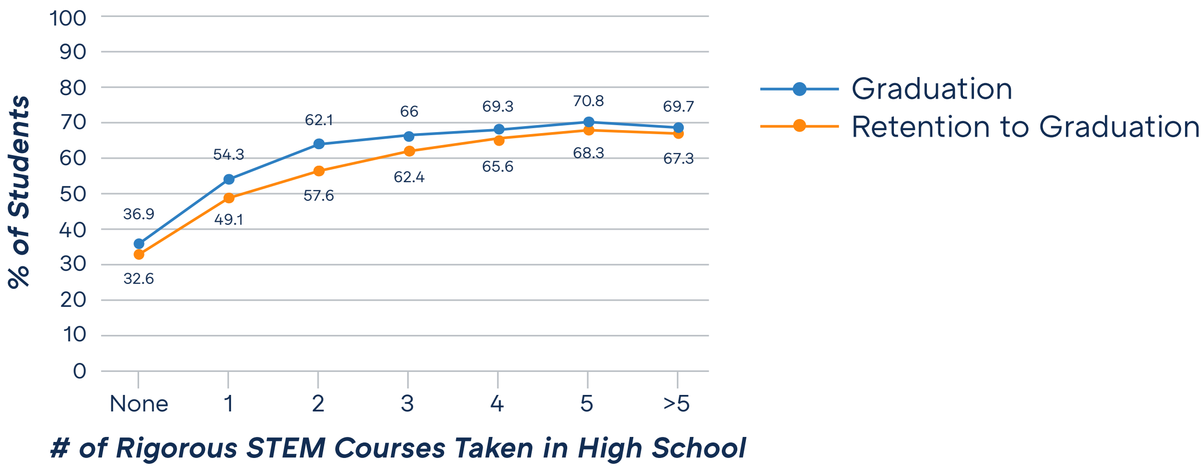
Persistence and retention to year three of postsecondary. Figure 12 displays the relationship between rigorous STEM enrollment and persistence and retention to year three of college. The association between rigorous STEM enrollment and retention to year three was stronger than rigorous STEM enrollment and persistence to year three. For persistence to year three, there was a steady increase from 69% for students who did not participate in rigorous STEM to 85.2% who participated in one course, peaking at 96.1% for students who participated in five rigorous STEM courses. For retention to year three, there also was a gradual increase from 52.8% for students who did not participate in rigorous STEM to 70% for students who enrolled in one course, peaking at 88.9% for students who participated in five rigorous STEM courses. The differences between proportions were significant for both persistence to year three ($\chi^2(1, N = 135{,}954) = 7{,}221.44, p < .001$) and for retention to year three ($\chi^2(1, N = 135{,}954) = 8{,}575.63, p < .001$) and both associations were moderate ($V = .260$ and $V = .271$, respectively).

FIGURE 12: Persistence and Retention to Third Year by Number of Rigorous STEM Courses Taken in High School



Graduation within four years and retention to college graduation. Figure 13 displays the relationship between rigorous STEM course-taking and graduation within four years and retention to college graduation. The association between rigorous STEM enrollment and graduation within four years was stronger than rigorous STEM enrollment and retention to graduation. For graduation, there was a steady increase from 36.9% for students who did not enroll in rigorous STEM to 54.3% for students who enrolled in just one rigorous STEM course, peaking at 70.8% for students who enrolled in five rigorous STEM courses. For college retention, there was a gradual increase from 32.6% for students who did not enroll in rigorous STEM to 49.1% for students who participated in one rigorous STEM course, peaking at 68.3% for students who participated in five rigorous STEM courses. The difference between proportions was significant for both graduation within four years ($\chi^2(1, N = 68{,}497) = 3495.93, p < .001$) and for retention to graduation ($\chi^2(1, N = 68{,}497) = 3487.09, p < .001$) and the association between rigorous STEM enrollment and college graduation was moderate ($V = .247$), while the relationship between rigorous STEM enrollment and college retention was small ($V = .182$).

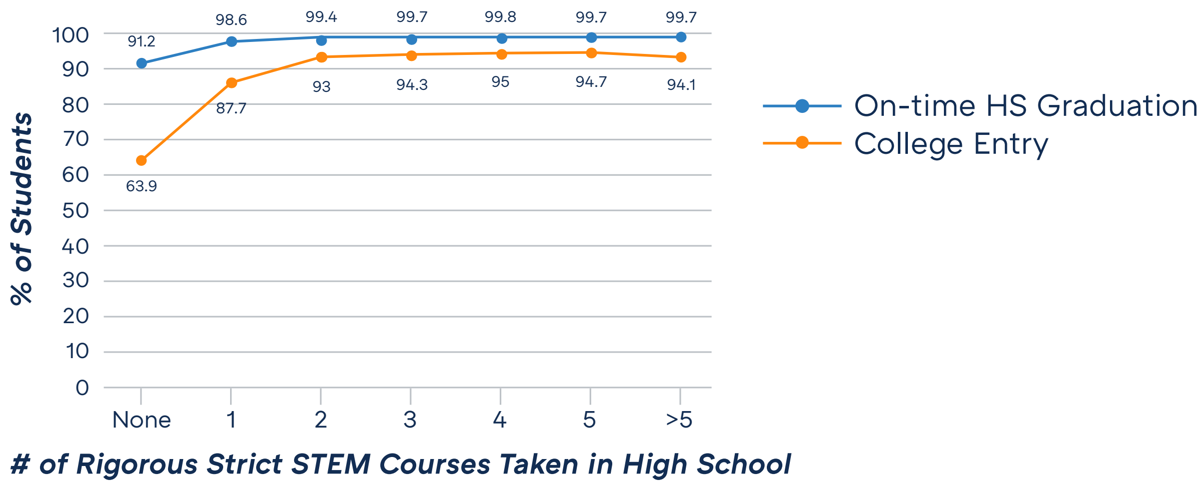
FIGURE 13: Graduation within Four Years and Retention to College Graduation by Number of Rigorous STEM Courses Taken in High School



Rigorous Strict STEM Course Enrollment

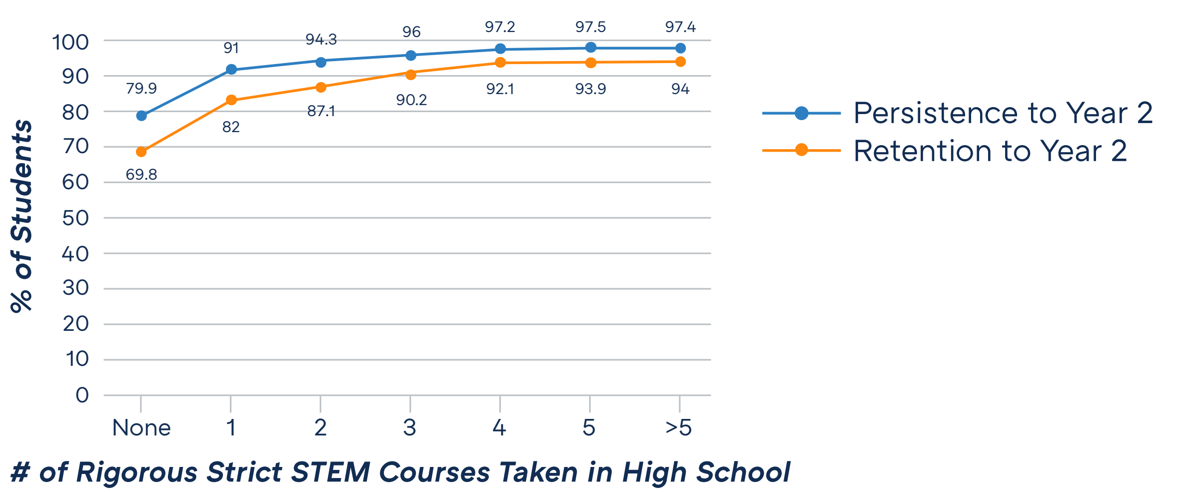
On-time high school graduation and college enrollment. Due to limited enrollment in rigorous lenient STEM courses, only the effects of rigorous strict STEM course enrollment will be discussed. Figure 14 displays the relationship between rigorous strict STEM enrollment, high school graduation, and college enrollment. The association between rigorous strict STEM enrollment and college enrollment was stronger than rigorous strict STEM enrollment and high school graduation. For high school graduation, there was a steady increase from 91.2% for those who did not participate in rigorous strict STEM to 98.6% for those who enrolled in just one rigorous strict STEM course, peaking at 99.8% for students who enrolled in four rigorous strict STEM courses. For college enrollment, there was a gradual increase from 63.9% for students who did not enroll in rigorous strict STEM to 87.7% for those who participated in one course, peaking at 95% for students who enrolled in four rigorous strict STEM courses. The differences between proportions were significant for on-time high school graduation ($\chi^2(1, N = 340{,}738) = 5{,}151.3$, $p < .001$) and for college enrollment ($\chi^2(1, N = 315{,}143) = 18{,}394.26$, $p < .001$) and the association between enrollment in rigorous strict STEM and high school graduation was small ($V = .147$), while the association between rigorous strict STEM participation and college enrollment was moderate ($V = .281$).

FIGURE 14: On-time High School Graduation and Postsecondary Entry by Rigorous Strict STEM Courses Taken in High School



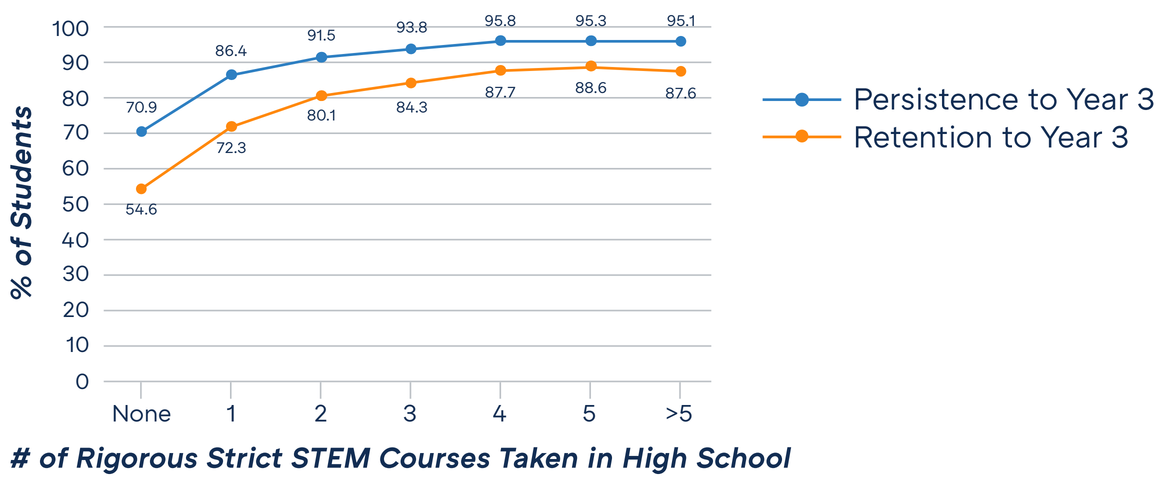
Persistence and retention to year two of postsecondary. The relationship between rigorous strict STEM enrollment and persistence and retention to year two of college can be found in Figure 15. The association between rigorous strict STEM enrollment and retention to year two was slightly stronger than rigorous strict STEM and persistence to year two. For persistence to year two, there was a gradual increase from 79.9% for students who did not participate in rigorous strict STEM to 91% for students who enrolled in one course, peaking at 97.5% for students who enrolled in five rigorous strict STEM courses. For retention to year two, there was a steady increase from 69.8% for those who did not participate in rigorous strict STEM to 82% for those who enrolled in one course, peaking at 94% for students who enrolled in more than five rigorous strict STEM courses. The differences between proportions were significant for both persistence to two (χ^2(1, N = 203,098) = 6,187.13, p < .001) and for retention to year two (χ^2(1, N = 203,098) = 6,916.94, p < .001) and both associations were small but approaching moderate (V = .196 and V = .199).

FIGURE 15: Persistence and Retention to Second Year by Number of Rigorous Strict STEM Courses Taken in High School



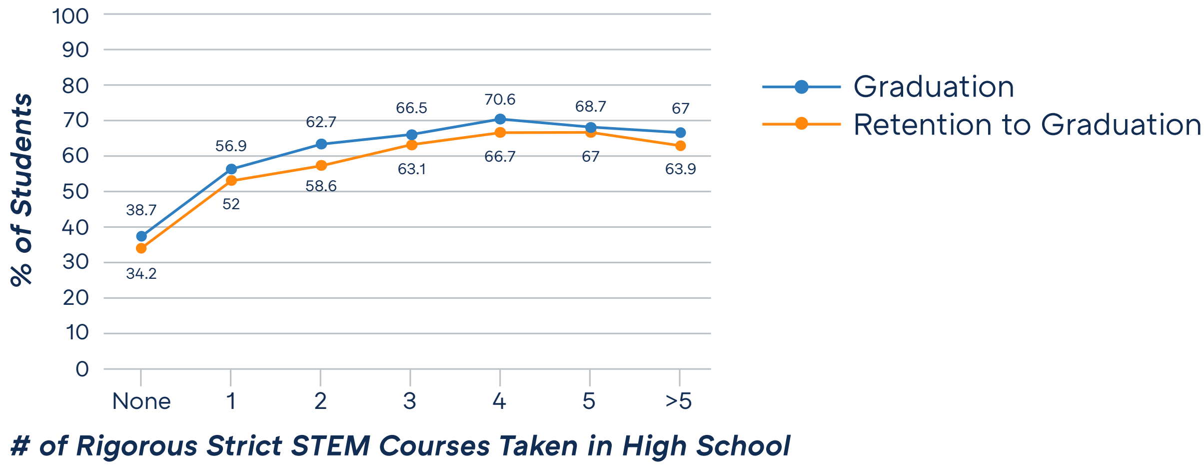
Persistence and retention to year three of postsecondary. Figure 16 displays the association between rigorous strict STEM course-taking and persistence and retention to year three of college. The relationship between rigorous strict STEM enrollment and retention to year three is slightly stronger than the relationship between rigorous strict STEM enrollment and persistence to year three. For persistence to year three, there was a gradual increase from 70.9% for students who did not participate in rigorous strict STEM to 86.4% for students who enrolled in one course, peaking at 95.8% for students who enrolled in four rigorous strict STEM courses. For retention to year three, there was a gradual increase from 54.6% for students who did not participate in rigorous strict STEM to 72.3% for students who enrolled in one course, peaking at 88.6% for students who enrolled in five rigorous strict STEM courses. The difference between proportions was significant for both persistence to year three ($\chi^2(1, N = 135{,}954) = 5{,}988.46$, $p < .001$) and for retention to year three ($\chi^2(1, N = 135{,}954) = 7{,}397.8$, $p < .001$) and both effects were moderate ($V = .235$ and $V = .253$, respectively).

FIGURE 16: Persistence and Retention to Third Year by Number of Rigorous Strict STEM Courses Taken in High School



Graduation within four years and retention to on-time college graduation. The association between rigorous strict STEM course-taking and graduation within four years and retention to college graduation is shown in Figure 17. The relationship between rigorous strict STEM enrollment and graduation within four years is stronger than rigorous strict STEM enrollment and retention to graduation. For graduation, there was a gradual increase from 38.7% for those who did not participate in rigorous strict STEM to 56.9% for those who enrolled in one course, peaking at 70.6% for students who participated in four rigorous strict STEM courses. For retention to graduation, there was a steady increase from 34.2% for those who did not participate in rigorous strict STEM to 52% for those who enrolled in one course, peaking at 67% for those who enrolled in five rigorous strict STEM courses. The differences between proportions were significant for both graduation within four years ($\chi^2(1, N = 68{,}497) = 2{,}897$, $p < .001$) and for retention to graduation ($\chi^2(1, N = 68{,}497) = 2{,}889.36$, $p < .001$). The association between rigorous strict STEM enrollment and college graduation was moderate ($V = .229$) and the association between enrollment in rigorous strict STEM courses and college retention was small ($V = .168$).

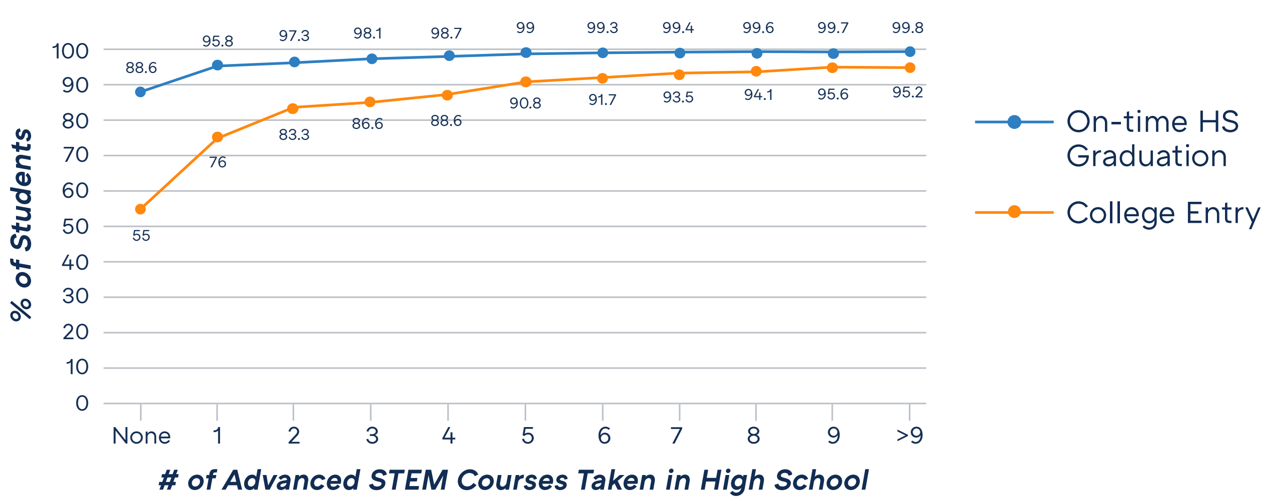
FIGURE 17: Graduation within Four Years and Retention to College Graduation by Number of Rigorous Strict STEM Courses Taken in High School



Advanced STEM Course Enrollment

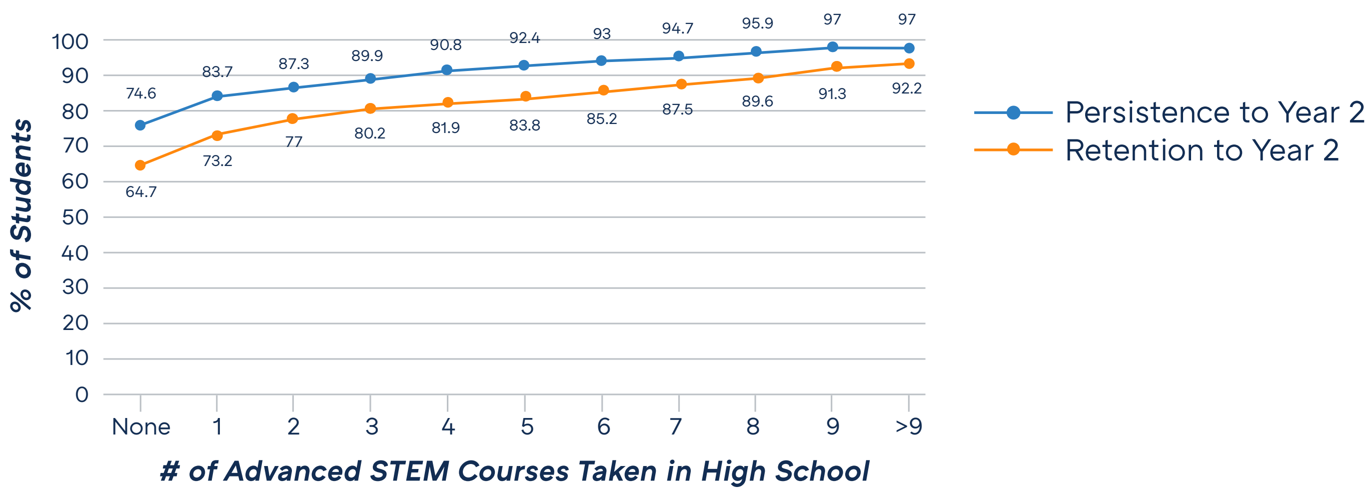
On-time high school graduation and college enrollment. Figure 18 displays the associations between advanced STEM course enrollment and high school graduation and college enrollment. The relationship between advanced STEM enrollment and college enrollment was stronger than advanced STEM enrollment and high school graduation. For high school graduation, there was a steady increase from 88.6% for students who did not participate in advanced STEM to 95.8% for those who enrolled in just one advanced STEM course, peaking at 99.8% for students who participated in more than nine advanced STEM courses. For college enrollment, there was a gradual increase from 55% for those who did not participate in advanced STEM to 76% for those who enrolled in one class, peaking at 95.6% for students who enrolled in nine advanced STEM courses. The differences between proportions were significant for high school graduation (χ^2(1, N = 340,738) = 8,831.93, $p < .001$) and for college enrollment (χ^2(1, N = 315,143) =31,870.13, $p < .001$). The association between advanced STEM enrollment and high school graduation was small, approaching moderate (V = .195) and the association between advanced STEM enrollment and college enrollment was strong (V = .367).

FIGURE 18: On-time High School Graduation and Postsecondary Entry by Advanced STEM Courses Taken in High School



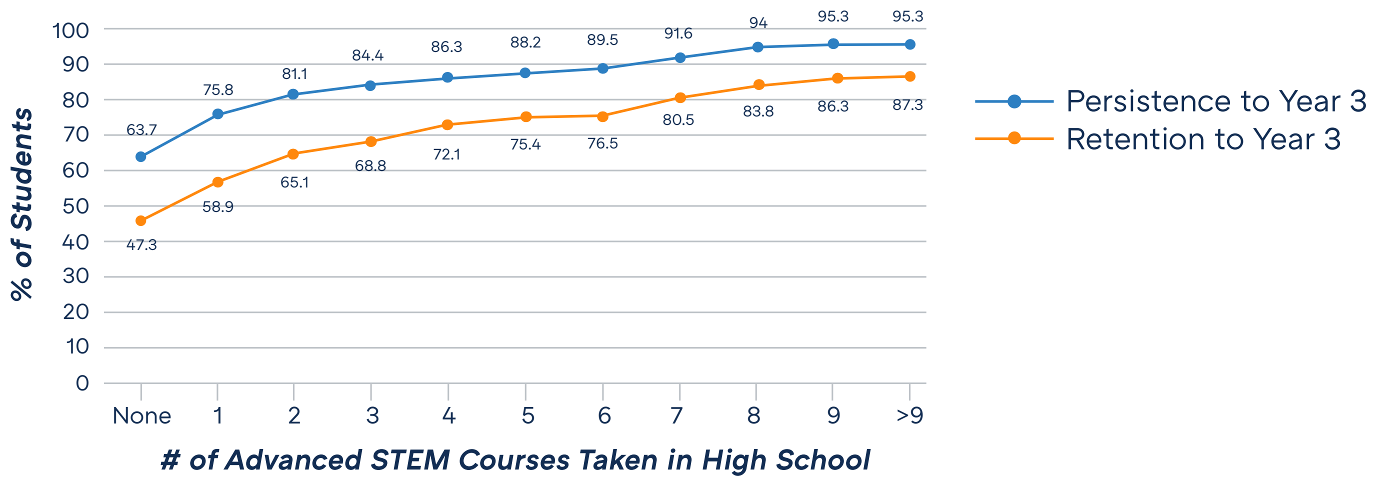
Persistence and retention to year two of postsecondary. Figure 19 displays the associations between advanced STEM course-taking and persistence and retention to year two of college. The relationship between advanced STEM enrollment and persistence to year two is slightly stronger than the association between advanced STEM and retention to year two. For persistence to year two, there was a gradual increase from 74.6% for those who did not participate in advanced STEM to 83.7% for those who participated in one course, peaking at 97% for those who enrolled in nine advanced STEM courses. For retention to year two, there was a steady increase from 64.7% for students who did not participate in advanced STEM to 73.2% for those who enrolled in one course, peaking at 92.2% for those who enrolled in more than nine advanced STEM courses. The differences between proportions were significant for both persistence to year two ($\chi^2(1, N = 203{,}098) = 9{,}561.48$, $p < .001$) and for retention to year two ($\chi^2(1, N = 203{,}098) = 6{,}916.94$, $p < .001$) and both associations were moderate ($V = .238$ and $V = .228$, respectively).

FIGURE 19: Persistence and Retention to Second Year by Number of Advanced STEM Courses Taken in High School



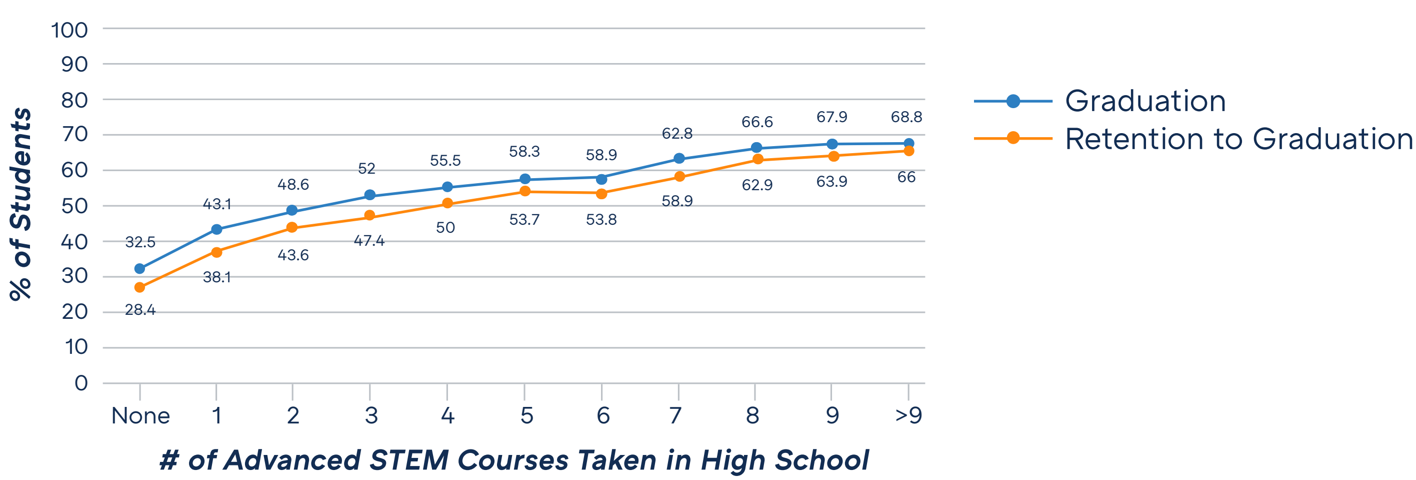
Persistence and retention to year 3 of postsecondary. The relationships between advanced STEM course-taking and persistence and retention to year three of college are shown in Figure 20. The association between advanced STEM enrollment and retention to year three is slightly stronger than advanced STEM and persistence to year three. For persistence to year three, there was a steady increase from 63.7% for those who did not participate in advanced STEM to 75.8% who enrolled in one class, peaking at 95.3% for those who participated in nine advanced STEM courses. For retention to year three, there was a gradual increase from 47.3% for those who did not enroll in advanced STEM to 58.9% for those who participated in one course, peaking at 87.3% for those who enrolled in more than nine advanced STEM courses. The differences between proportions were significant for both persistence to year three ($\chi^2(1, N = 135{,}954) = 9{,}416.06$, $p < .001$) and for retention to year three ($\chi^2(1, N = 135{,}954) = 10{,}711.66$, $p < .001$) and both associations were moderate, approaching strong ($V = .286$ and $V = .292$, respectively).

FIGURE 20: Persistence and Retention to Third Year by Number of Advanced STEM Courses Taken in High School



Graduation within four years and retention to on-time college graduation. The associations between advanced STEM course-taking and graduation within four years and retention to college graduation are shown in Figure 21. The relationship between advanced STEM enrollment and college graduation was stronger than advanced STEM enrollment and retention to graduation. For graduation within four years, there was a gradual increase from 32.5% for students who did not participate in advanced STEM to 43.1% for students who participated in one course, peaking at 68.8% for those who enrolled in more than nine advanced STEM courses. For retention to graduation, there was a steady increase from 28.4% for students who did not participate in advanced STEM to 38.1% for those who enrolled in one course, peaking at 66% for those who enrolled in more than nine advanced STEM courses. The differences between proportions were significant for both graduation within four years ($\chi^2(1, N = 68{,}497) = 4{,}146.07, p < .005$) and for retention to graduation ($\chi^2(1, N = 68{,}497) = 4{,}136.62, p < .001$). The association between advanced STEM enrollment and college graduation was moderate ($V = .256$) and the relationship between advanced STEM enrollment and retention to graduation was small ($V = .188$).

FIGURE 21: Graduation within Four Years and Retention to College Graduation by Number of Advanced STEM Courses Taken in High School



Logistic Regression: The Effects of STEM Enrollment Variables on Postsecondary Outcomes.

Logistic Regression was used to measure the effect of STEM course-taking patterns on on-time high school graduation (within four years) and postsecondary outcomes, such as enrollment, persistence, retention, and degree attainment within four years after high school graduation. Appendix H shows the independent variables and covariates that were tested individually for significance. Logistic regression was used because all outcomes were binary. The analyses were exploratory in nature, which allowed for the examination of several individual variables and their association with high school and postsecondary outcomes related to STEM education. In this phase of analysis, logistic regression examined the differences in effects of the individual significant independent variables, in isolation and in the context of additional explanatory variables, as well as the cumulative effects of variables associated with the highest amount of explained variance in the final statistically significant models.

Tables 1 through 8 show the statistically significant variables when tested individually and the final models associated with the highest amount of explained variance for each outcome. In all models, both the number of enrolled rigorous STEM courses and the number of enrolled advanced STEM courses are statistically significant independent variables; however, in most cases the number of advanced STEM courses taken is associated with a slightly higher amount of variance in outcomes. Given that the definition of advanced STEM courses includes rigorous STEM courses (see definition in Appendix A), the number of advanced STEM courses taken was the variable used in the final models. Further, in addition to testing the effects of economically disadvantaged status, EL status, and special education status, an independent variable called historically underperforming was included. Historically underperforming includes students within the special education, EL, and economically disadvantaged student groups. As the tables in the final models show, in all cases, both historically underperforming and economically disadvantaged indicators were statistically significant. Given this, two final models are included, one that includes historically underperforming and one that includes economically disadvantaged. In all cases the difference in association when comparing final models with economically disadvantaged versus historically underperforming is very small or there is no difference. The effects of two interactions for historically underperforming and economically disadvantaged status and number of advanced STEM courses were tested. None of the interactions tested were found to be statistically significant.

Logistic Regression Results. Logistic regression analysis results indicate that there is a statistically significant association between the number of rigorous STEM and number of advanced STEM courses a student in PA takes throughout high school and on-time graduation and all postsecondary outcomes. As the final models show, the effect of taking STEM courses in high school remains significant even after holding all other explanatory variables constant. A comparison of the Odds Ratio (Exp(β)) for the effect of the number of advanced STEM courses on outcomes individually, versus after holding all other significant explanatory variables constant, shows a significant increase in odds regardless.

The probability of on-time high school graduation (R^2 = .14 & .13) and postsecondary enrollment (R^2 = .22 & .21) was found to have a statistically significant association with the number of advanced STEM courses taken in high school and whether a student is economically disadvantaged or part of the historically underperforming student group. The odds of a student graduating on-time from high school increases by a factor of 1.633 (Model 1 in Table 1) to 1.692 (Model 2 in Table 1) and the odds of a student enrolling in a postsecondary institution increases by a factor of 1.392 (Model 1 in Table 2) to 1.419 (Model 2 in Table 2) when the number of advanced STEM courses increases by one.

For persistence to year two and three, retention to year two and three, and graduation within four years following high school completion, enrollment status at entry (part versus full-time) and institution type at entry (2 versus 4-year) were both found have a very large effect. Additionally, institution sector (public versus private) and being White versus not (WHITE) were found to have large effects for postsecondary graduation within four years. The probability of a student persisting to year two (R^2 = .21) or three (R^2 = .25) and remaining at the same school to year two (R^2 = .14) or three (R^2 = .22) was found to be significantly associated with the number of advanced STEM courses taken in high school, enrollment status at entry (part-time/full-time), the type of institution (2- versus 4-year) and whether a student is economically disadvantaged or part of the historically underperforming student group. The odds for persistence to year two and year three are 2.8 and 2.3 times higher respectively for students who had a full-time status at entry and 2.6 (year two) and 3.3 (year three) times higher respectively for students who enrolled in 4-year institutions at entry.

Holding all other significant explanatory variables constant, the odds of a student persisting to year two and year three increases by a factor of 1.17 and a high of 1.18 (Model 2 in Tables 3 and 5) respectively when the number of enrolled advanced STEM courses increases by one. As reflected in Tables 4 and 6, the effect of advanced STEM course-taking in high school is similar for retention to year two and three. However, the effect of enrolling in a 2-year versus 4-year institution at entry is smaller for retention to year two and much larger for retention to year three. The odds for retention to year 3 are 3.7 times higher for students who enroll in 4-year institutions at entry. Although it could seem logical to conclude that students enrolled in a 2-year institution could exit postsecondary after the completion of a 2-year degree or potentially transfer to a 4-year institution to continue their education, this was not observed among students in these cohorts. Only a small percentage of students (24%) who began at a 2-year institution at entry into postsecondary earned a degree (any degree) within four years after high school graduation.

The probability of graduating within four years of high school graduation (any degree) was found to be significantly associated with the number of advanced STEM courses taken in high school, enrollment status at entry (part-time/full-time), the type of institution (2 versus 4-year), institution sector (public versus private), ethnicity (White versus non-White), and whether a student is economically disadvantaged or part of the historically underperforming student group (R^2 = .18 & .17). Holding other significant explanatory variables constant, the odds for postsecondary graduation within four years of high school completion are 3.0 times higher for students who had an initial full-time entry status and 1.3 times higher for students who enrolled in 4-year institutions at entry. The odds of graduation within four years are 1.8 times higher for students who attended a private institution compared to a public institution. For postsecondary graduation within four years, holding all other significant explanatory variables constant, the significant effect of the number of advanced STEM courses taken in high school remains. The odds of a student graduating within four years of high school graduation increases by a factor of 1.11 when the number of advanced STEM courses increases by one.

The final models with the highest amount of explained variance (R^2 = .27 & .26) were for degree type (Associate's versus Bachelor's or above) and if a student graduated within four years of high school graduation. These results indicate that the probability of obtaining a Bachelor's degree within four years of high school graduation is significantly associated with the number of advanced STEM courses taken in high school, the institution sector at entry (public/private), enrollment status at entry (part-time/full-time), and whether a student is economically disadvantaged or part of the historically underperforming student group. The largest effect for obtaining a Bachelor's degree within four years is associated with part-time versus full-time status at entry into postsecondary. For those who graduated, the odds of graduating with a Bachelor's degree within four years are ten times higher for students who had a full-time status at entry into postsecondary versus part-time, and 2.6 times higher if a student attended a private versus public institution. The effect of the number of advanced STEM courses taken in high school remains the same when holding other explanatory variables constant. The odds of a student graduating with a Bachelor's degree within four years of high school graduation increases by a factor of 1.4 when the number of advanced STEM courses increases by one.

For all final models, students in the historically underperforming and economically disadvantaged student group had a lower probability ($p < .0001$) of on-time high school graduation, postsecondary enrollment, persistence, retention, and postsecondary graduation within four years of high school completion when compared to other students. Additionally, ethnicity, specifically, White versus non-White, was only found to be significantly associated with the probability of graduating within four years with the odds of graduating 1.84 times higher for students in the White ethnic category when compared to non-White.

The prediction accuracy for a favorable outcome (on-time high school graduation, postsecondary enrollment, persistence, retention, and graduation within four years) based on the final models varied. All but two final models had a prediction accuracy of over 90% (range of 90% - 100%) for a favorable outcome, graduation within four years (63%) and postsecondary enrollment (84%). All models except for graduation within four years show a reasonably high or high level of sensitivity, predicting a favorable outcome for students.

These findings indicate a significant effect of advanced STEM course-taking for students in the presently studied cohorts from PA high schools, even after controlling for other significant explanatory variables. The odds of on-time graduation from high school, postsecondary enrollment, persisting to year two and three, remaining at the same college, graduating within four years of high school completion, and graduating with a Bachelor's degree increases with each additional advanced STEM course taken.

Logistic Regression Final Models - STEM

TABLE 1: Logistic Regression Analysis of On-time High School Graduation

Statistically Significant Individual Independent Variables	β	Se β	Wald's X^2	*df*	*p*	Exp(β) Odds Ratio	Model X^2 (*p*)	Pseudo R^2	*n*
# Rigorous STEM Courses	1.527	.024	4001.8	1	.0001	4.605	11906.8 (.0001)	.09	340738
# Advanced STEM Courses	.575	.008	5675.24	1	.0001	1.78	14533.4 (.0001)	.11	340738
Historically Underperforming Status (Yes=1; No=0)	-1.445	.016	8614.6	1	.0001	.236	9875.4 (.0001)	.08	340738
Economically Disadvantaged Status (Yes=1; No=0)	-1.166	.014	6650.9	1	.0001	.312	6870.9 (.0001)	.05	340738
Final Models*									
Model 1							**19131.8 (.0001)**	**.14**	**340738**
Constant	2.779	.014	39003.5	1	.0001	16.1			
# Advanced STEM Courses**	.490	.007	4297.053	1	.0001	1.633			
Historically Underperforming Status (Yes=1; No=0)	-1.026	.016	4152.5	1	.0001	.358			
Model 2							**17951.9 (.0001)**	**.13**	**340738**
Constant	2.559	.012	47051.5	1	.0001	12.927			
# Advanced STEM Courses**	.526	.008	4830.9	1	.0001	1.692			
Economically Disadvantaged Status (Yes=1; No=0)	-.839	.015	3317.8	1	.0001	.432			

*Final Models include all independent variables that were significant when tested individually and remained significant.

**Advanced STEM Courses includes Rigorous STEM Courses and was included in the final model since both were significant individually, but a greater amount of variance is associated with Advanced Courses.

TABLE 2: Logistic Regression Analysis of Postsecondary Enrollment

Statistically Significant Individual Independent Variables	β	Se β	Wald's X^2	*df*	*p*	Exp(β) Odds Ratio	Model X^2 (*p*)	Pseudo R^2	*n*
# Rigorous STEM Courses	.865	.007	17015.8	1	.0001	2.375	31474.5 (.0001)	.14	315143
# Advanced STEM Courses	.377	.002	23572.7	1	.0001	1.458	41127.6 (.0001)	.18	315143
Historically Underperforming Status (Yes=1; No=0)	-1.23	.008	22173.9	1	.0001	.292	22912.9 (.0001)	.10	315143
Economically Disadvantaged Status (Yes=1; No=0)	-1.032	.008	15567.2	1	.0001	.356	15597.9 (.0001)	.07	315143
Final Models*									
Model 1							**51459.4 (.0001)**	**.22**	**315143**
Constant	.834	.007	14455.4	1	.0001	2.303			
# Advanced STEM Courses**	.331	.002	18186.6	1	.0001	1.392			
Historically Underperforming Status (Yes=1; No=0)	-.880	.009	10189.7	1	.0001	.415			
Model 2							**48616.5 (.0001)**	**.21**	**315143**
Constant	.692	.006	12070.4	1	.0001	1.998			
# Advanced STEM Courses**	.350	.002	20213.41	1	.0001	1.419			
Economically Disadvantaged Status (Yes=1; No=0)	-.753	.09	7490.4	1	.0001	.471			

*Final Models include all independent variables that were significant when tested individually and remained significant.

**Advanced STEM Courses includes Rigorous STEM Courses and was included in the final model since both were significant individually, but a greater amount of variance is associated with Advanced Courses.

TABLE 3: Logistic Regression Analysis of Postsecondary Persistence to Year 2

Statistically Significant Individual Independent Variables	β	Se β	Wald's X^2	*df*	*p*	Exp(β) Odds Ratio	Model X^2 (*p*)	Pseudo R^2	*n*
# Rigorous STEM Courses	.632	.008	6280.5	1	.0001	1.882	10077.24 (.0001)	.09	203098
# Advanced STEM Courses	.258	.003	8016.9	1	.0001	1.295	11474.5 (.0001)	.10	203098
Enrollment Status at Entry (Part-time=0; Full-time=1)	1.948	.018	11975.6	1	.0001	7.017	10712.2 (.0001)	.10	191306
Years (2-year=0; 4-year=1)	1.674	.013	15594.0	1	.0001	5.334	15097.23 (.0001)	.13	202791
Historically Underperforming Status (Yes=1; No=0)	-1.165	.013	8132.8	1	.0001	.312	7983.93 (.0001)	.07	203098
Economically Disadvantaged Status (Yes=1; No=0)	-1.091	.013	6910.5	1	.0001	.336	6610.8 (.0001)	.06	203098
Final Models*									
Model 1							**22742.1 (.0001)**	**.21**	**191088**
Constant	.256	.019	175.31	1	.0001	1.292			
# Advanced STEM Courses**	.152	.003	2281.4	1	.0001	1.164			
Enrollment Status at Entry (Part-time=0; Full-time=1)	1.043	.021	2568.3	1	.0001	2.838			
Years (2-year=0; 4-year=1)	.954	.017	3150.2	1	.0001	2.596			
Historically Underperforming Status (Yes=1; No=0)	-.669	.015	1945.9	1	.0001	.512			
Model 2							**22953.3 (.0001)**	**.21**	**191088**
Constant	.192	.019	107.31	1	.0001	1.212			
# Advanced STEM Courses**	.157	.003	2449.6	1	.0001	1.170			
Enrollment Status at Entry (Part-time=0; Full-time=1)	1.064	.021	2673.6	1	.0001	2.897			
Years (2-year=0; 4-year=1)	.976	.017	3315.3	1	.0001	2.655			
Economically Disadvantaged Status (Yes=1; No=0)	-.715	.015	2187.6	1	.0001	.489			

*Final Model includes all independent variables that were significant when tested individually and remained significant.

**Advanced STEM Courses includes Rigorous STEM Courses and was included in the final model since both were significant individually, but a greater amount of variance is associated with Advanced Courses.

TABLE 4: Logistic Regression Analysis of Postsecondary Retention to Year 2

Statistically Significant Individual Independent Variables	β	Se β	Wald's X^2	*df*	*p*	Exp(β) Odds Ratio	Model X^2 (*p*)	Pseudo R^2	*n*
# Rigorous STEM Courses	.435	.005	7023.4	1	.0001	1.545	9539.0 (.0001)	.07	203098
# Advanced STEM Courses	.185	.002	8654.4	1	.0001	1.203	10674.5 (.0001)	.08	203098
Enrollment Status at Entry (Part-time=0; Full-time=1)	1.538	.017	8172.9	1	.0001	4.656	7839.3 (.0001)	.06	191306
Years (2-year=0; 4-year=1)	1.209	.012	10614.4	1	.0001	3.350	10285.8 (.0001)	.08	202791
Historically Underperforming Status (Yes=1; No=0)	-.843	.011	5873.27	1	.0001	.430	5747.4 (.0001)	.04	203098
Economically Disadvantaged Status (Yes=1; No=0)	-.801	.011	4959.4	1	.0001	.449	4803.23 (.0001)	.035	203098
Final Models*									
Model 1							**22742.1 (.0001)**	**.21**	**191088**
Constant	-.115	.018	1227.6	1	.0001	.645			
# Advanced STEM Courses**	.122	.002	3102.4	1	.0001	1.129			
Enrollment Status at Entry (Part-time=0; Full-time=1)	.879	.019	2066.6	1	.0001	2.408			
Years (2-year=0; 4-year=1)	.593	.014	1675.6	1	.0001	1.810			
Historically Underperforming Status (Yes=1; No=0)	-.439	.013	1227.6	1	.0001	.645			
Model 2							**22953.3 (.0001)**	**.21**	**191088**
Constant	-.151	.018	73.5	1	.0001	.860			
# Advanced STEM Courses**	.124	.002	3256.4	1	.0001	1.132			
Enrollment Status at Entry (Part-time=0; Full-time=1)	.891	.019	2127.6	1	.0001	2.437			
Years (2-year=0; 4-year=1)	.607	.014	1762.9	1	.0001	1.835			
Economically Disadvantaged Status (Yes=1; No=0)	-.480	.013	1406.2	1	.0001	.619			

*Final Model include all independent variables that were significant when tested individually and remained significant.

**Advanced STEM Courses includes Rigorous STEM Courses and was included in the final model since both were significant individually, but a greater amount of variance is associated with Advanced Courses.

TABLE 5: Logistic Regression Analysis of Postsecondary Persistence to Year 3

Statistically Significant Individual Independent Variables	β	Se β	Wald's X^2	*df*	*p*	Exp(β) Odds Ratio	Model X^2 (*p*)	Pseudo R^2	*n*
# Rigorous STEM Courses	.640	.008	6070.3	1	.0001	1.896	9517.4 (.0001)	.11	135954
# Advanced STEM Courses	.264	.003	7885.8	1	.0001	1.302	11091.9 (.0001)	.12	135954
Enrollment Status at Entry (Part-time=0; Full-time=1)	1.889	.021	8154.9	1	.0001	6.613	7986.8 (.0001)	.10	128149
Years (2-year=0; 4-year=1)	1.828	.015	15310.2	1	.0001	6.219	15339.2 (.0001)	.17	135763
Historically Underperforming Status (Yes=1; No=0)	-1.201	.014	7526.5	1	.0001	.301	7430.8 (.0001)	.08	135954
Economically Disadvantaged Status (Yes=1; No=0)	-1.126	.014	6288.6	1	.0001	.324	6094.4 (.0001)	.07	135594
Final Models*									
Model 1							**22042.9 (.0001)**	**.25**	**128023**
Constant	-.304	.023	175.9	1	.0001	.738			
# Advanced STEM Courses**	.160	.003	2472.6	1	.0001	1.173			
Enrollment Status at Entry (Part-time=0; Full-time=1)	.839	.024	1193.6	1	.0001	2.315			
Years (2-year=0; 4-year=1)	1.181	.018	4341.0	1	.0001	3.258			
Historically Underperforming Status (Yes=1; No=0)	-.734	.016	2075.2	1	.0001	.480			
Model 2							**22189.1 (.0001)**	**.25**	**128023**
Constant	-.376	.022	286.8	1	.0001	.687			
# Advanced STEM Courses**	.166	.003	2646.5	1	.0001	1.180			
Enrollment Status at Entry (Part-time=0; Full-time=1)	.861	.024	1259.6	1	.0001	2.366			
Years (2-year=0; 4-year=1)	1.207	.018	4541.1	1	.0001	3.342			
Economically Disadvantaged Status (Yes=1; No=0)	-.779	.022	286.8	1	.0001	.687			

*Final Models include all independent variables that were significant when tested individually and remained significant.

**Advanced STEM Courses includes Rigorous STEM Courses and was included in the final model since both were significant individually, but a greater amount of variance is associated with Advanced Courses.

TABLE 6: Logistic Regression Analysis of Postsecondary Retention to Year 3

Statistically Significant Individual Independent Variables	β	Se β	Wald's X^2	*df*	*p*	Exp(β) Odds Ratio	Model X^2 (*p*)	Pseudo R^2	*n*
# Rigorous STEM Courses	.469	.005	7369.9	1	.0001	1.598	9827.2 (.0001)	.10	135954
# Advanced STEM Courses	.205	.002	9475.6	1	.0001	1.227	11547.4 (.0001)	.11	135954
Enrollment Status at Entry (Part-time=0; Full-time=1)	1.578	.022	5297.02	1	.0001	4.845	5824.2 (.0001)	.06	128149
Years (2-year=0; 4-year=1)	1.781	.014	15196.8	1	.0001	5.993	16617.7 (.0001)	.16	135763
Historically Underperforming Status (Yes=1; No=0)	-.916	.012	5456.6	1	.0001	.400	5477.5 (.0001)	.05	135954
Economically Disadvantaged Status (Yes=1; No=0)	-.866	.013	4469.3	1	.0001	.421	4467.9 (.0001)	.04	135954
Final Models*									
Model 1							**21899.6 (.0001)**	**.22**	**128023**
Constant	-1.009	.024	1804.6	1	.0001	.365			
# Advanced STEM Courses**	.129	.002	3207.9	1	.0001	1.138			
Enrollment Status at Entry (Part-time=0; Full-time=1)	.490	.025	381.2	1	.0001	1.632			
Years (2-year=0; 4-year=1)	1.297	.017	5998.7	1	.0001	3.660			
Historically Underperforming Status (Yes=1; No=0)	-.475	.014	1110.5	1	.0001	.622			
Model 2							**22048.3 (.0001)**	**.22**	**128023**
Constant	-1.045	.023	2012.9	1	.0001	.352			
# Advanced STEM Courses**	.131	.002	3348.2	1	.0001	1.140			
Enrollment Status at Entry (Part-time=0; Full-time=1)	.501	.025	400.54	1	.0001	1.651			
Years (2-year=0; 4-year=1)	1.313	.017	6151.3	1	.0001	3.716			
Economically Disadvantaged Status (Yes=1; No=0)	-.524	.015	1259.9	1	.0001	.592			

*Final Models include all independent variables that were significant when tested individually and remained significant.

**Advanced STEM Courses includes Rigorous STEM Courses and was included in the final model since both were significant individually, but a greater amount of variance is associated with Advanced Courses.

TABLE 7: Logistic Regression Analysis of Postsecondary Graduation within 4 Years

Statistically Significant Individual Independent Variables	β	Se β	Wald's X^2	*df*	*p*	Exp(β) Odds Ratio	Model X^2 (*p*)	Pseudo R^2	*n*
# Rigorous STEM Courses	.469	.005	7369.9	1	.0001	1.598	9827.2 (.0001)	.10	135954
# Advanced STEM Courses	.205	.002	9475.6	1	.0001	1.227	11547.4 (.0001)	.11	135954
Enrollment Status at Entry (Part-time=0; Full-time=1)	1.578	.022	5297.02	1	.0001	4.845	5824.2 (.0001)	.06	128149
Years (2-year=0; 4-year=1)	1.781	.014	15196.8	1	.0001	5.993	16617.7 (.0001)	.16	135763
Historically Underperforming Status (Yes=1; No=0)	-.916	.012	5456.6	1	.0001	.400	5477.5 (.0001)	.05	135954
Economically Disadvantaged Status (Yes=1; No=0)	-.866	.013	4469.3	1	.0001	.421	4467.9 (.0001)	.04	135954
Final Model 1							**21899.6 (.0001)**	**.22**	**128023**
Constant	-1.009	.024	1804.6	1	.0001	.365			
# Advanced STEM Courses**	.129	.002	3207.9	1	.0001	1.138			
Enrollment Status at Entry (Part-time=0; Full-time=1)	.490	.025	381.2	1	.0001	1.632			
Years (2-year=0; 4-year=1)	1.297	.017	5998.7	1	.0001	3.660			
Historically Underperforming Status (Yes=1; No=0)	-.475	.014	1110.5	1	.0001	.622			
Final Model 2							**22048.3 (.0001)**	**.22**	**128023**
Constant	-1.045	.023	2012.9	1	.0001	.352			
# Advanced STEM Courses**	.131	.002	3348.2	1	.0001	1.140			
Enrollment Status at Entry (Part-time=0; Full-time=1)	.501	.025	400.54	1	.0001	1.651			
Years (2-year=0; 4-year=1)	1.313	.017	6151.3	1	.0001	3.716			
Economically Disadvantaged Status (Yes=1; No=0)	-.524	.015	1259.9	1	.0001	.592			

*Final Models include all independent variables that were significant when tested individually and remained significant.

**Advanced STEM Courses includes Rigorous STEM Courses and was included in the final model since both were significant individually, but a greater amount of variance is associated with Advanced Courses.

TABLE 8: Logistic Regression Analysis of Postsecondary Graduation with an Associate's versus Bachelor's (or Higher) Degree Within Four Years

Statistically Significant Individual Independent Variables	β	Se β	Wald's X^2	*df*	*p*	Exp(β) Odds Ratio	Model X^2 (*p*)	Pseudo R^2	*n*
# Rigorous STEM Courses	.855	.021	1644.7	1	.0001	2.350	2874.6 (.0001)	.15	31217
# Advanced STEM Courses	.347	.007	2136.6	1	.0001	1.414	3328.5 (.0001)	.18	32117
Enrollment Status at Entry (Part-time=0; Full-time=1)	1.150	.043	702.4	1	.0001	3.157	848.7 (.0001)	.05	30303
Years (2-year=0; 4-year=1)	2.685	.081	1092.7	1	.0001	14.659	1153.9 (.0001)	.07	29278
Historically Underperforming Status (Yes=1; No=0)	-1.271	.035	1303.3	1	.0001	.2818	1205.3 (.0001)	.07	31217
Economically Disadvantaged Status (Yes=1; No=0)	-1.063	.039	736.5	1	.0001	.345	667.7 (.0001)	.04	30303
Final Model 1							**4799.0 (.0001)**	**.27**	**29278**
Constant	-1.283	.106	147.4	1	.0001	.277			
# Advanced STEM Courses**	.311	.008	1442.3	1	.0001	1.365			
Enrollment Status at Entry (Part-time=0; Full-time=1)	.985	.048	428.3	1	.0001	2.678			
Years (2-year=0; 4-year=1)	2.354	.093	645.8	1	.0001	10.53			
Historically Underperforming Status (Yes=1; No=0)	-.993	.044	511.8	1	.0001	.371			
Final Model 2							**4614.8 (.0001)**	**.26**	**29278**
Constant	-1,428	.105	184.8	1	.0001	.240			
# Advanced STEM Courses**	.321	.008	1534.7	1	.0001	1.379			
Enrollment Status at Entry (Part-time=0; Full-time=1)	.973	.047	421.5	1	.0001	2.645			
Years (2-year=0; 4-year=1)	2.370	.092	664.2	1	.0001	10.71			
Economically Disadvantaged Status (Yes=1; No=0)	-.849	.047	322.2	1	.0001	.428			

*Final Models include all independent variables that were significant when tested individually and remained significant.

**Advanced STEM Courses includes Rigorous STEM Courses and was included in the final model since both were significant individually, but a greater amount of variance is associated with Advanced Courses.

Sub-Question #2:

Are postsecondary trajectories differentially affected by advanced STEM courses taken early in high school as opposed to later in high school?

Sample Descriptive Breakdown

For all students who had all four years of course data, 4.1% enrolled in an early timed (freshman or sophomore year) rigorous STEM course, while 32.4% enrolled in one or more late timed (junior or senior year) rigorous STEM courses. Only 3.4% of students enrolled in one or more early timed rigorous strict STEM courses and 27.9% of students participated in one or more late timed rigorous strict STEM courses. Lastly, 35.3% of students participated in an advanced STEM course during freshman or sophomore year, while 46.1% enrolled in an advanced STEM course during junior or senior year.

The Relationship between STEM Timing Variables and Postsecondary Outcomes

Chi square analyses were used to examine the relationship between the timing of first exposure (early versus late timing) to advanced and rigorous STEM courses and postsecondary outcomes. Independent timing variables included the timing of students' first rigorous STEM course, first rigorous strict STEM course, and the timing of their first advanced STEM course. Dependent postsecondary measures included on-time graduation from high school, enrollment in college, persistence and retention year to year, on-time college graduation, and final major (STEM or non-STEM) at graduation. While the effects of early timing for rigorous STEM and rigorous strict STEM were tested on all outcome variables, the results are not reported as only 4% of students participated in one of these courses during their freshman or sophomore years. As timing comparisons for rigorous STEM and rigorous strict STEM are not available without both early and late timed courses, only timing for advanced STEM courses is reported.

Advanced STEM Course Timing

On-time high school graduation and college enrollment. Figure 22 displays the relationship between early timing (freshman or sophomore year) advanced STEM enrollment, high school graduation, and college enrollment. The association between early advanced STEM course enrollment and postsecondary enrollment was stronger than early advanced STEM courses and high school graduation. For high school graduation, there was a gradual increase from 91.1% for students who did not enroll in early advanced STEM courses to 96.1% for students who participated in one course, peaking at 100% for students who enrolled in eight early advanced STEM courses. For college enrollment, there was a steady increase from 63.1% for students who did not participate in early advanced STEM to 80.7% for students who enrolled in one course, peaking at 93.6% for those who enrolled in five early advanced STEM courses. The differences between proportions were significant for both on-time high school graduation ($\chi^2(1, N = 340{,}319) = 5{,}445.57, p < .001$) and for college enrollment ($\chi^2(1, N = 314{,}908) = 20{,}635.48, p < .001$). The association between early timed advanced STEM course enrollment and on-time high school graduation was small ($V = .137$), while the relationship between early advanced STEM enrollment and college enrollment was moderate ($V = .276$).

FIGURE 22: On-time High School Graduation and Postsecondary Entry by Advanced STEM Courses Taken Early in High School

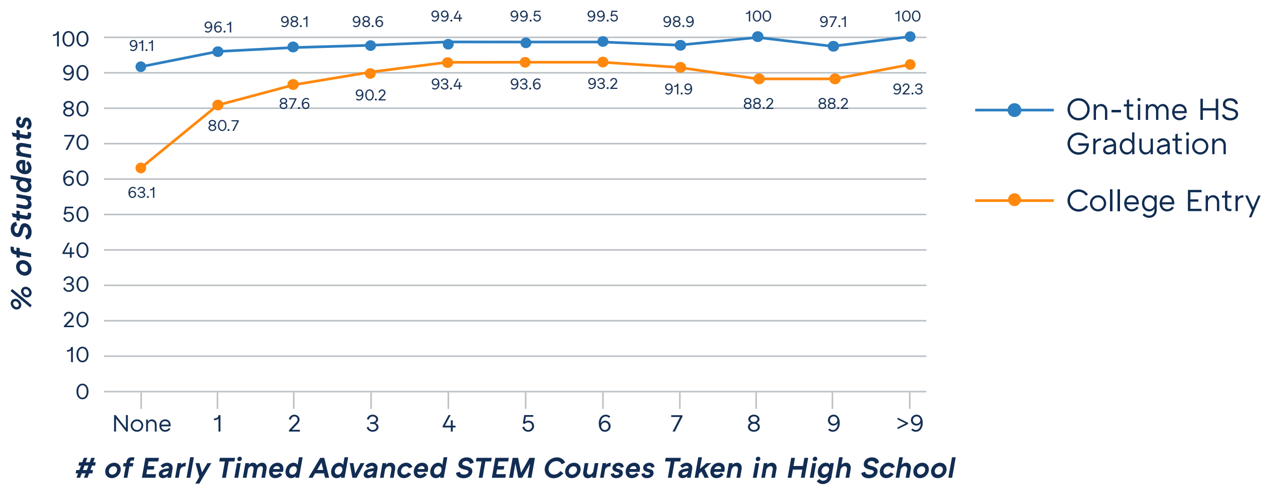
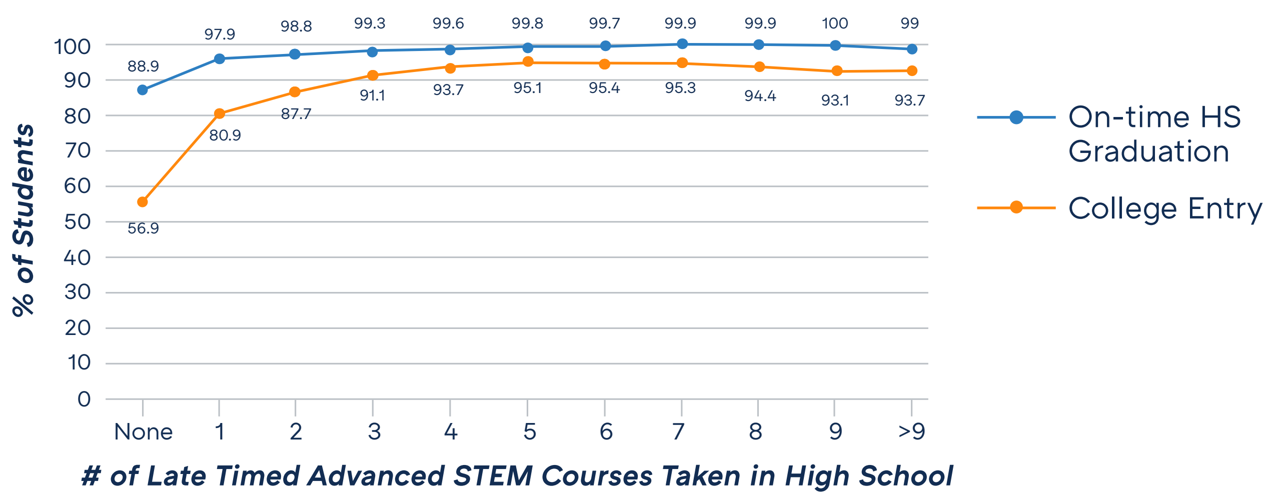


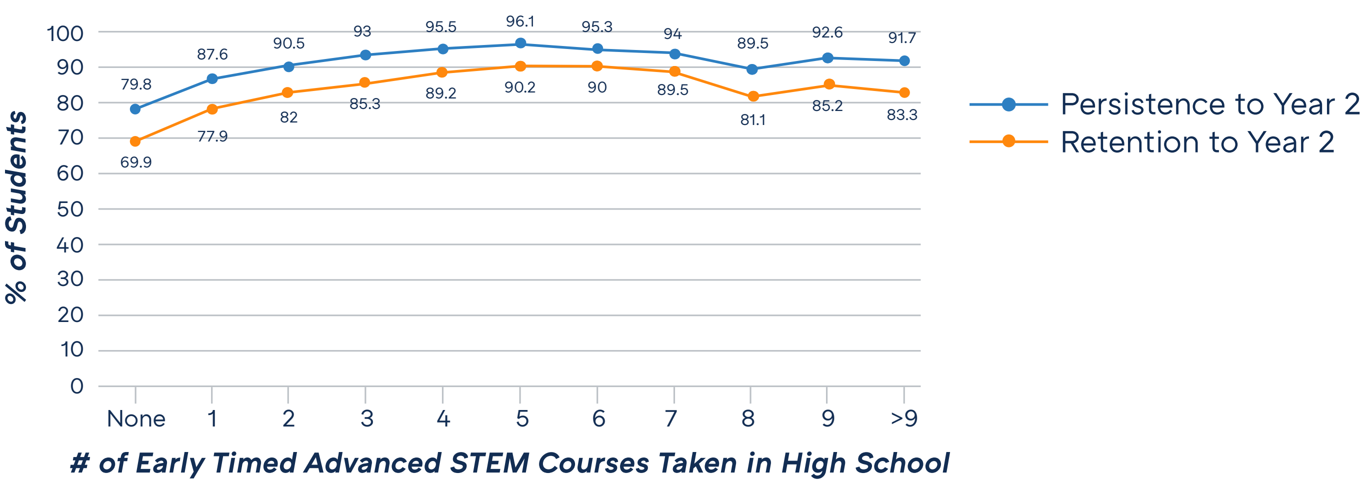
Figure 23 displays the association between late advanced STEM course-taking and high school graduation and college enrollment. The association between late advanced STEM and college enrollment is stronger than late advanced STEM and high school graduation. For high school graduation, there is a steady increase from 88.9% for students who did not participate in late advanced STEM to 97.9% for those who enrolled in one course, peaking at 100% for students who enrolled in nine late advanced STEM courses. For college enrollment, there was a gradual increase from 56.9% for those who did not participate in late advanced STEM to 80.9% for those who enrolled in one course, peaking at 95.4% for those who enrolled in six late timed advanced STEM courses. The differences between proportions were significant for both high school graduation ($\chi^2(1, N = 340{,}319) = 9{,}222.21$, $p < .001$) and for college enrollment ($\chi^2(1, N = 314{,}908) = 31{,}215.8$, $p < .001$). The association between enrollment in late timed advanced STEM courses and high school graduation was moderate ($V = .203$), while the relationship between late advanced STEM courses and college enrollment was strong ($V = .362$).

FIGURE 23: On-time High School Graduation and Postsecondary Entry by Advanced STEM Courses Taken Late in High School



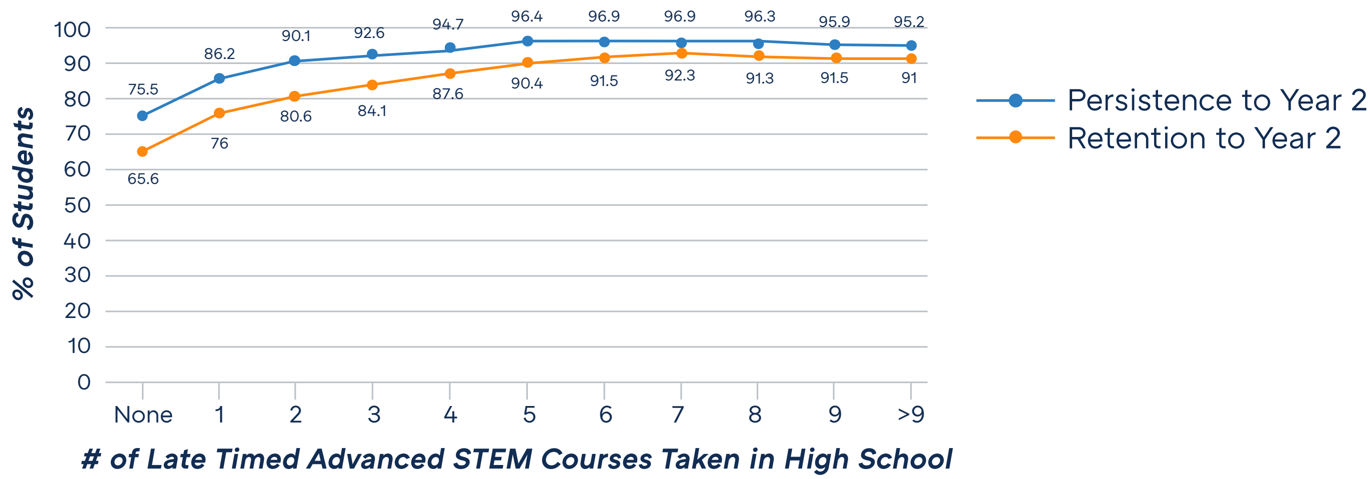
Persistence and retention to year two of postsecondary. Figure 24 displays the relationships between enrollment in early advanced STEM courses and persistence and retention to year two in college. The association between enrollment in early advanced STEM courses and persistence to year two was of similar strength to the relationship between early advanced STEM and retention to year two. For persistence to year two, there was a gradual increase from 79.8% for students who did not enroll in early advanced STEM to 87.6% for students who enrolled in one course, peaking at 96.1% for students who participated in five early timed advanced STEM courses. For retention to year two, there was a steady increase from 69.9% for students who did not enroll in early advanced STEM to 77.9% for those who participated in one course, peaking at 90% for those who enrolled in six early advanced STEM courses. The differences between proportions were significant for both persistence to year two ($\chi^2(1, N = 202{,}965) = 6{,}072.15, p < .001$) and for retention to year two ($\chi^2(1, N = 202{,}965) = 6{,}072.15, p < .001$) and both associations were small ($V = .182$).

FIGURE 24: Persistence and Retention to Second Year by Number of Advanced STEM Courses Taken Early in High School



The association between late advanced STEM courses and persistence and retention to year two are found in Figure 25. Specifically, the relationship between late advanced STEM enrollment and persistence to year two is stronger than late advanced STEM enrollment and retention to year two. For persistence to year two, there was a steady increase from 75.5% for students who did not participate in late advanced STEM to 86.2% for those who enrolled in just one course, peaking at 96.9% for those who enrolled in six late advanced STEM courses. For retention to year three, there was a gradual increase from 65.6% for students who did not enroll in late advanced STEM to 76% for students who participated in one course, peaking at 92.3% for students who enrolled in seven advanced STEM courses. The difference in proportions was significant for both persistence to year two ($\chi^2(1, N = 202{,}965) = 9{,}320.23, p < .001$) and for retention to year two ($\chi^2(1, N = 202{,}965) = 9{,}320.57, p < .001$) and both associations were moderate ($V = .237$ and $V = .227$, respectively).

FIGURE 25: Persistence and Retention to Second Year by Number of Advanced STEM Courses Taken Late in High School



Persistence and retention to year three of postsecondary. Figure 26 shows the relationship between early advanced STEM course enrollment and persistence and retention to year three of college. The relationship between early advanced STEM enrollment and retention to year three is similar in strength compared to the association between early STEM enrollment and persistence to year three. For persistence to year three, there was a steady increase from 70.8% for students who did not enroll in early advanced STEM courses to 81.3% for those who participated in one course, peaking at 93.5% for students who enrolled in five early advanced STEM courses. For retention to year three, there was a gradual increase from 54.7% for those who did not participate in early advanced STEM to 65.7% for those who enrolled in one course, peaking at 84.2% for students who enrolled in five early advanced STEM courses. The difference between proportions was significant for both persistence to year three ($\chi^2(1, N = 135{,}844) = 5{,}926.62$, $p < .001$) and retention to year three ($\chi^2(1, N = 135{,}844) = 6{,}935.12$, $p < .001$) and both associations were moderate ($V = .220$ and $V = .233$, respectively).

FIGURE 26: Persistence and Retention to Third Year by Number of Advanced STEM Courses Taken Early in High School

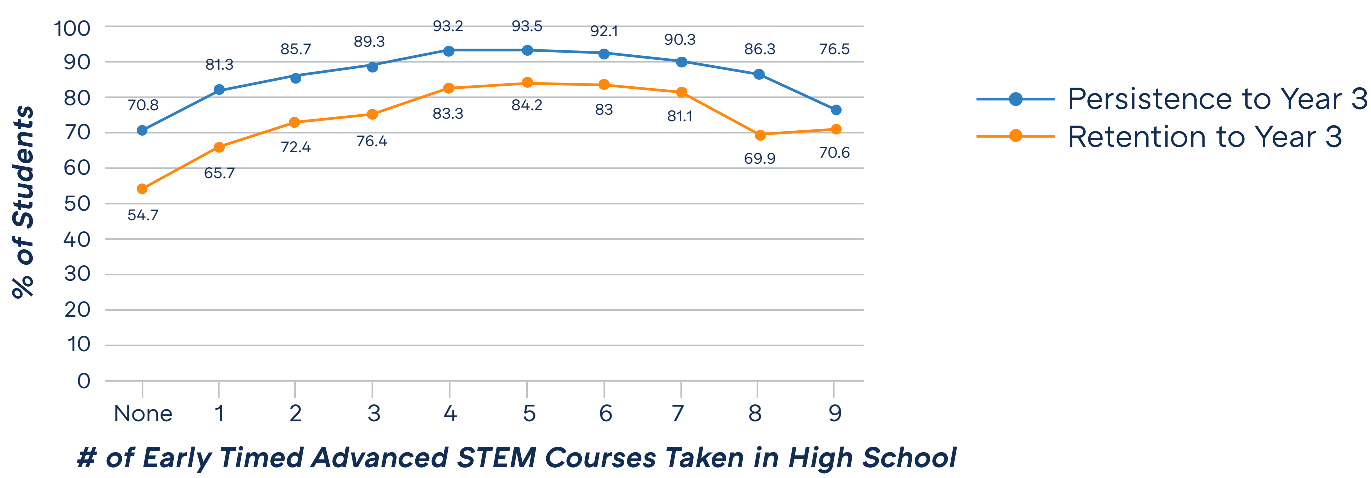
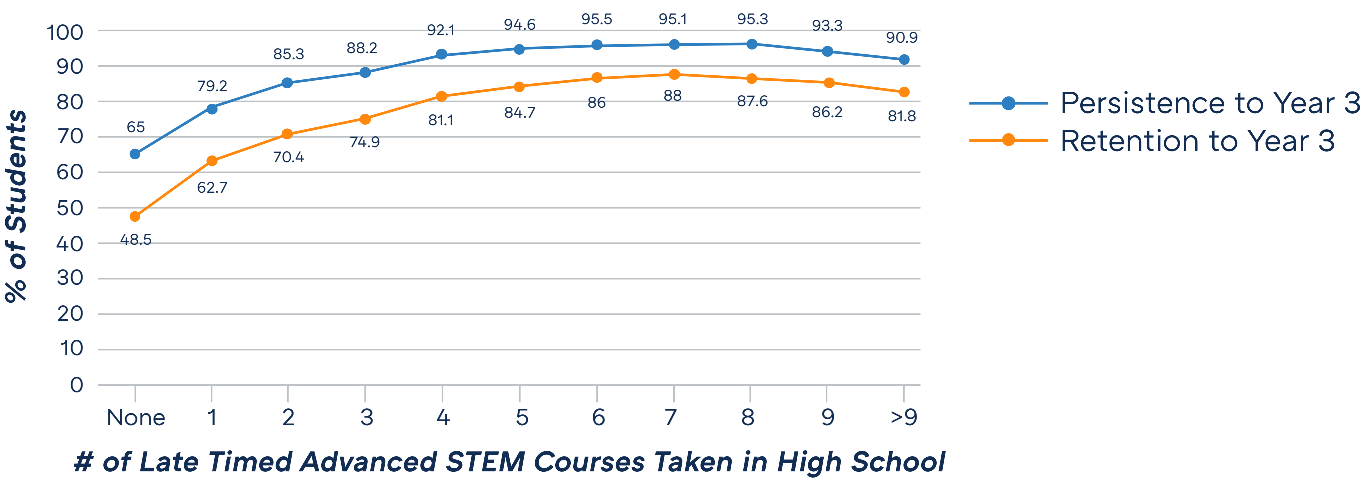


Figure 27 displays the relationship between late advanced STEM enrollment and college persistence and retention to year three. The association between late advanced STEM enrollment and persistence to year three is slightly stronger than late advanced STEM enrollment and retention to year three. For persistence to year three, there was a gradual increase from 65% for students without late advanced STEM enrollment to 79.2% for students who participated in one course, peaking at 95.5% for those who enrolled in six late advanced STEM courses. For retention to year three, there was a steady increase from 48.5% for students who had no enrollment in late advanced STEM to 62.7% for those who enrolled in one class, peaking at 88% for students who enrolled in seven late advanced STEM courses. The differences between proportions were significant for both persistence to year three ($\chi^2(1, N = 135{,}844) = 10{,}433.77$, $p < .001$) and retention to year three ($\chi^2(1, N = 135{,}844) = 9{,}251.26$, $p < .001$) and both associations were moderate, approaching strong ($V = .292$ and $V = .285$, respectively).

FIGURE 27: Persistence and Retention to Third Year by Number of Advanced STEM Courses Taken Late in High School



Graduation within four years and retention to on-time college graduation. Figure 28 displays the associations between early advanced STEM enrollment and graduation within four years and retention to college graduation. The relationship between early advanced STEM and graduation within four years was stronger than early advanced STEM enrollment and retention to graduation. For graduation, there was a gradual increase from 38.9% for students who did not enroll in early advanced STEM to 49.3% for those who enrolled in one course, peaking at 65.8% for students who enrolled in four early advanced STEM courses. For retention to graduation, there was a steady increase from 34.6% for students who did not participate in early advanced STEM to 44.4% for students who enrolled in one course, peaking at 62% for students who participated in five early advanced STEM courses. The differences between proportions were significant for both graduation within four years ($\chi^2(1, N = 68{,}462) = 2{,}727.87$, $p < .001$) and for retention to graduation ($\chi^2(1, N = 68{,}462) = 2{,}721.92$, $p < .001$). The association between enrollment in early timed advanced STEM courses and college graduation was moderate ($V = .208$), while the relationship between early advanced STEM enrollment and retention to graduation was small ($V = .152$).

FIGURE 28: Graduation within Four Years and Retention to College Graduation by Number of Advanced STEM Courses Taken Early in High School

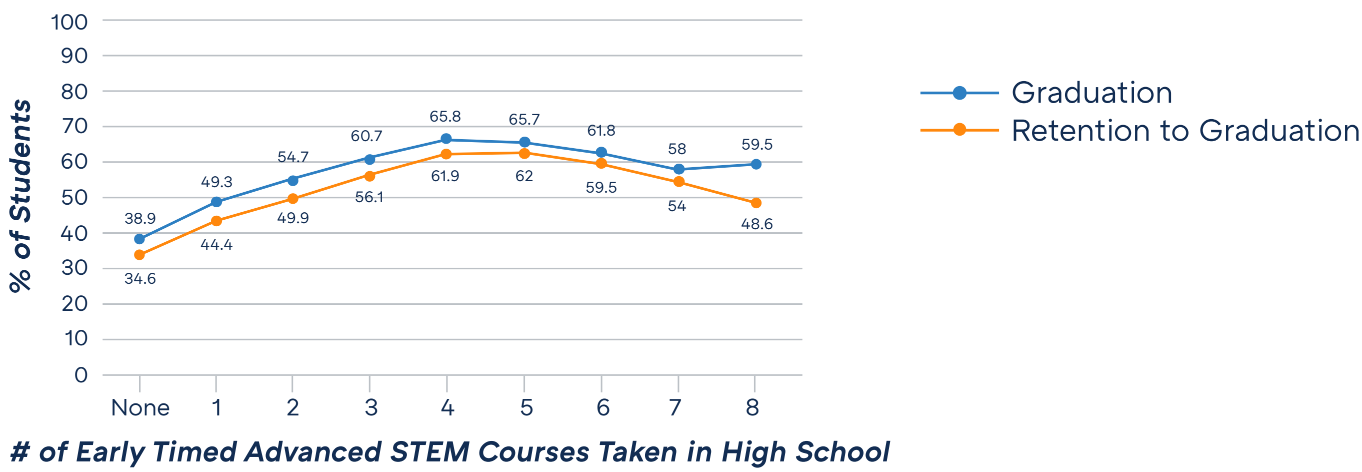
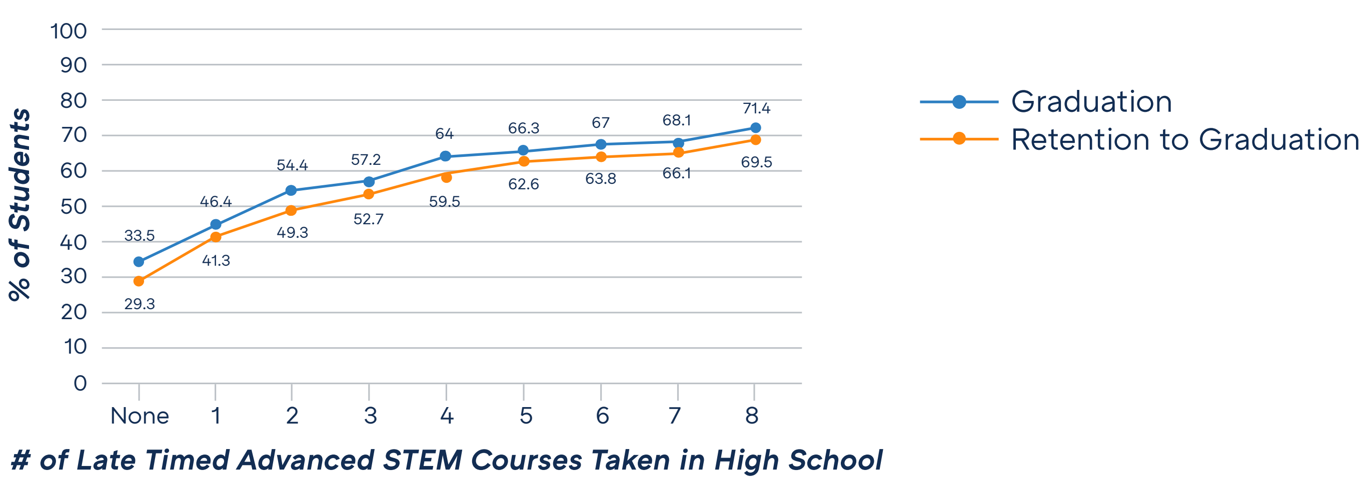


Figure 29 refers to the relationship between late advanced STEM enrollment and graduation within four years and retention to college graduation. The relationship between late advanced STEM enrollment and graduation within four years was stronger than late advanced STEM enrollment and retention to graduation. For graduation, there is a gradual increase from 33.5% for students who did not participate in late advanced STEM to 46.4% for those who enrolled in just one course, peaking at 71.4% for students who enrolled in eight late advanced STEM courses. For college retention, there was a similar steady increase from 29.3% for students who did not participate in late advanced STEM to 41.3% for those who enrolled in one course, peaking at 69.5% for those who enrolled in eight late advanced STEM courses. The difference between proportions for graduation ($\chi^2(1, N = 68{,}462) = 3{,}988.24$, $p < .001$) and retention to graduation ($\chi^2(1, N = 68{,}462) = 3{,}997.88$, $p < .001$) were significant. The association between enrollment in late timed advanced STEM courses and graduation within four years was moderate ($V = .256$), while the relationship between late advanced STEM enrollment and college retention was small ($V = .188$).

FIGURE 29: Graduation within Four Years and Retention to Graduation by Number of Advanced STEM Courses Taken Late in High School



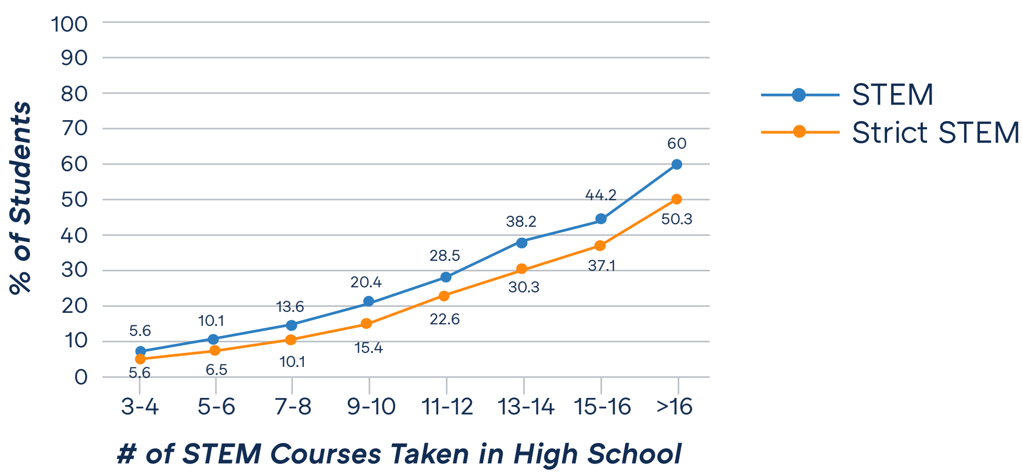
Sub-Question #3:

Are factors related to STEM education and the STEM employment availability in a student's county associated with his or her college major upon graduation?

College Graduation with a STEM or Strict STEM Degree

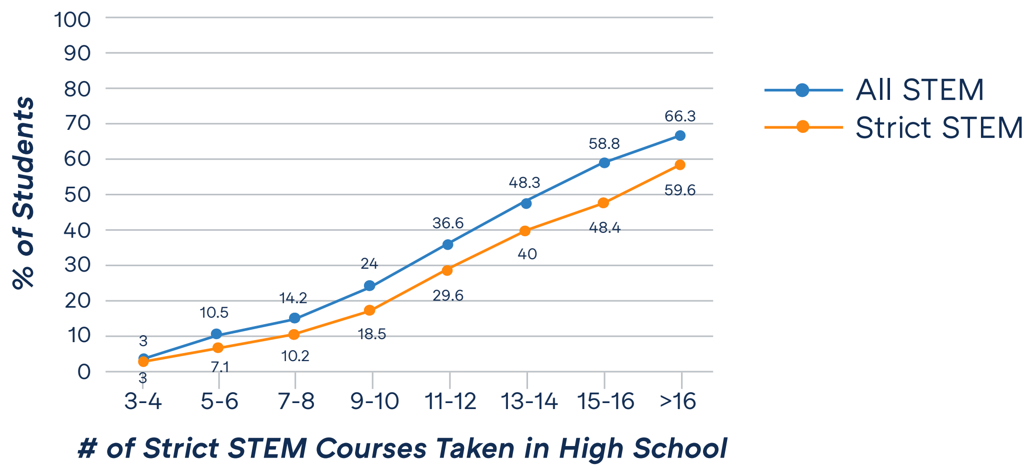
STEM Course Enrollment. Figure 30 shows the relationship between STEM course-taking patterns in high school and college major as STEM or non-STEM upon graduation. STEM course-taking had a stronger relationship with earning a STEM degree than a strict STEM degree. For earning a STEM degree, there was a gradual increase from 13.6% for students who enrolled in seven or eight STEM courses to 20.4% for those who enrolled in nine or ten, peaking at 60% for those who enrolled in more than 16 STEM courses. For graduating with a strict STEM major, there was a gradual increase from 10.1% for those who enrolled in seven or eight STEM courses to 15.4% for students who enrolled in nine or ten, peaking at 50.3% for students who participated in more than 16 STEM courses. The differences between proportions were significant for both earning a STEM degree ($\chi^2(1, N = 30{,}246) = 1{,}420.75$, $p < .001$) and earning a strict STEM degree ($\chi^2(1, N = 30{,}246) = 1{,}241.44$, $p < .001$) and both associations were moderate ($V = .219$ and $V = .204$, respectively).

FIGURE 30: STEM Degree Completion by STEM Courses Taken in High School



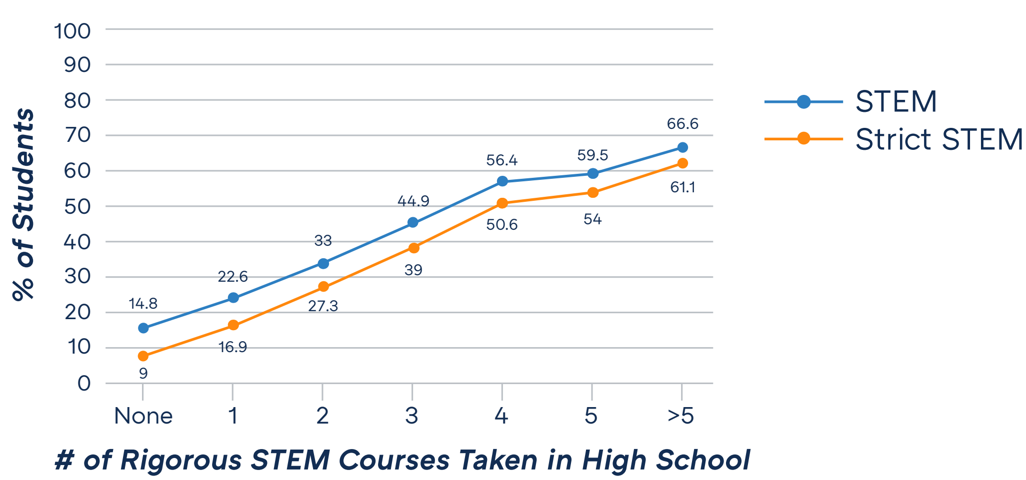
Strict STEM Course Enrollment. Figure 31 shows the relationship between strict STEM enrollment during high school and graduating college with a STEM and strict STEM major. The association between strict STEM course enrollment and STEM degree completion is stronger than strict STEM enrollment and strict STEM degree completion. For earning a STEM degree, there was a steady increase from 14.2% for those who enrolled in seven or eight strict STEM courses to 24% for those who enrolled in nine or ten, peaking at 66.3% for students who participated in over 16 strict STEM courses. For earning a strict STEM degree, there was a gradual increase from 10.2% for students who enrolled in seven or eight strict STEM courses to 18.5% for those who participated in nine or ten, peaking at 59.6% for students who enrolled in more than 16 strict STEM courses. The difference between proportions was significant for both earning a STEM degree ($\chi^2(1, N = 30{,}246) = 2{,}119.35$, $p < .001$) and a strict STEM degree ($\chi^2(1, N = 30{,}246) = 1{,}907.1$, $p < .001$) and both associations were moderate ($V = .267$ and $V = .253$, respectively).

FIGURE 31: STEM Degree Completion by Strict STEM Courses Taken in High School



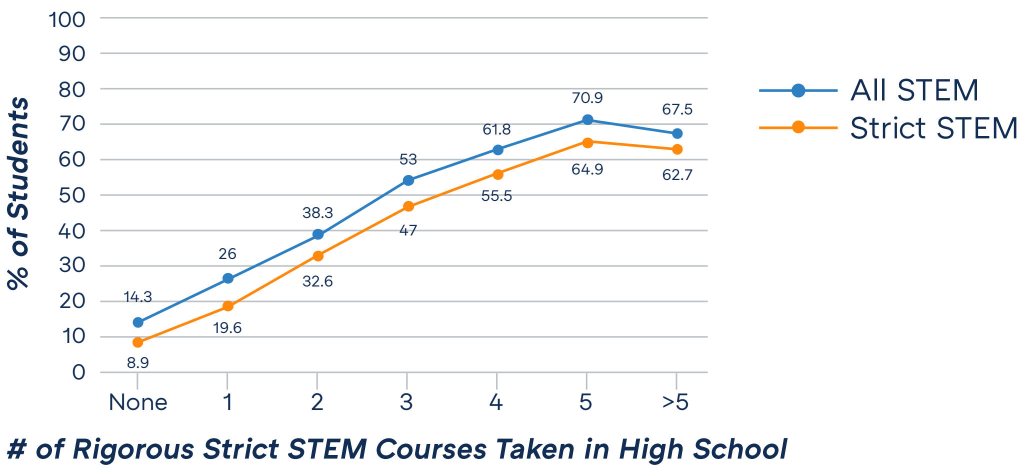
Rigorous STEM Course Enrollment. Figure 32 displays the relationship between rigorous STEM course enrollment and graduating college with a STEM or strict STEM degree. The association between rigorous STEM enrollment and earning a strict STEM degree was stronger than rigorous STEM enrollment and earning a STEM degree. For earning a STEM degree, there was a steady increase from 14.8% for those who did not enroll in any rigorous STEM to 22.6% for those who enrolled in one course, peaking 66.6% for students who enrolled in more than five rigorous STEM courses. For earning a strict STEM degree, there was a gradual increase from 9% for students who did not participate in rigorous STEM to 16.9% for those who enrolled in one course, peaking at 61.1% for students who enrolled in more than five rigorous STEM courses. The difference between proportions was significant for both earning a STEM degree ($\chi^2(1, N = 30{,}246) = 3{,}314.93, p < .001$) and a strict STEM degree ($\chi^2(1, N = 30{,}246) = 3{,}957.7, p < .001$) and both associations were strong ($V = .333$ and $V = .362$, respectively).

FIGURE 32: STEM Degree Completion by Rigorous STEM Courses Taken in High School



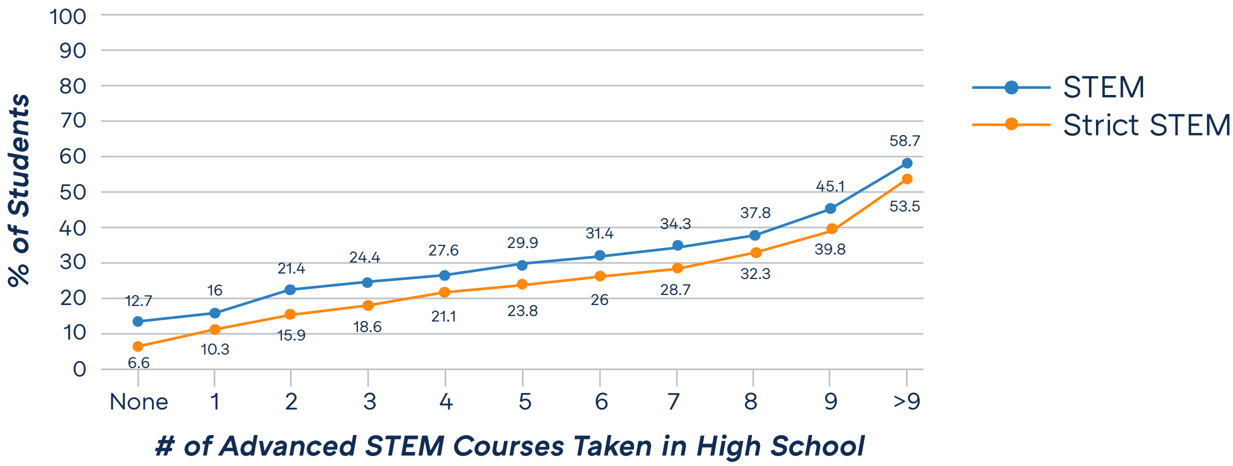
Rigorous Strict STEM Course Enrollment. The association between rigorous strict STEM course enrollment and graduating college with a STEM or strict STEM degree is shown in Figure 33. The relationship between rigorous strict STEM enrollment and earning a strict STEM major is stronger than rigorous strict STEM enrollment and earning a STEM major. For earning a STEM major, there is a gradual increase from 14.3% for students who did not enroll in rigorous strict STEM to 26% for enrollment in one course, peaking at 70.9% for those who enrolled in five rigorous strict STEM courses. For earning a strict STEM degree, there was also a steady increase from 8.9% for students who did not participate in rigorous strict STEM to 19.6% for students who enrolled in one course, peaking at 64.9% for students who enrolled in five rigorous strict STEM courses. The difference between proportions was significant for both earning a STEM degree ($\chi^2(1, N = 30{,}246) = 3{,}915.22$, $p < .005$) and for earning a strict STEM degree ($\chi^2(1, N = 30{,}246) = 4{,}521.71$, $p < .001$) and both associations were strong ($V = .363$ and $V = .390$, respectively).

FIGURE 33: STEM Degree Completion by Rigorous Strict STEM Courses Taken in High School



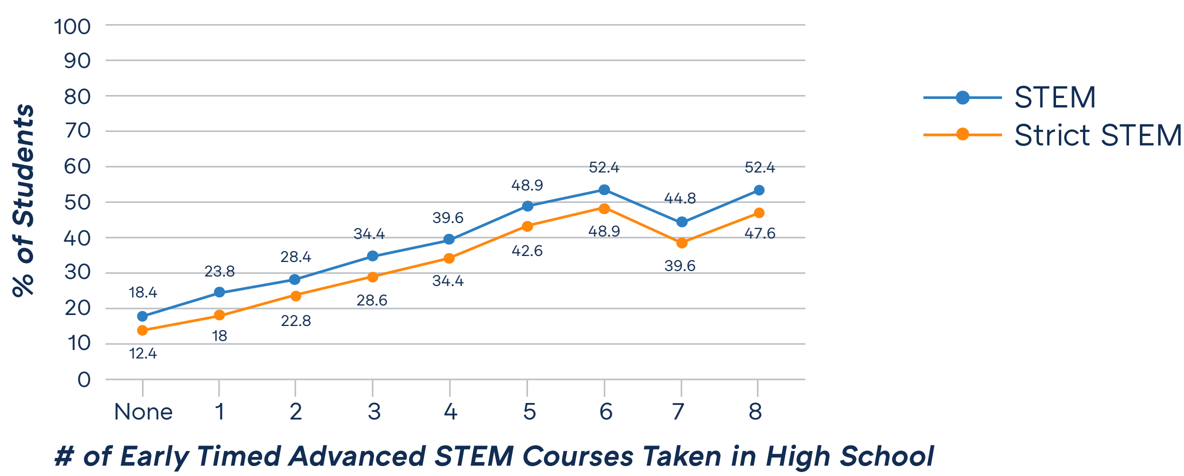
Advanced STEM Course Enrollment. Figure 34 examines the relationship between enrollment in advanced STEM courses during high school and earning a STEM or strict STEM degree in college. The association between advanced STEM enrollment and earning a strict STEM degree was stronger than advanced STEM enrollment and earning a STEM degree. For earning a STEM degree, there was a steady increase from 12.7% for students who did not participate in advanced STEM to 16% for those who enrolled in one course, peaking at 58.7% for those who participated in more than 9 advanced STEM courses. For earning a strict STEM degree, there was a similar gradual increase from 6.6% for students who enrolled in no advanced STEM courses to 10.3% for those who enrolled in one course, peaking at 53.5% for those who participated in more than 9 advanced STEM courses. The differences between proportions were significant for both earning a STEM degree ($\chi^2(1, N = 30{,}246) = 2{,}597.43$, $p < .001$) and for earning a strict STEM degree ($\chi^2(1, N = 30{,}246) = 3{,}156.1$, $p < .001$) and both associations were strong ($V = .302$ and $V = .333$, respectively).

FIGURE 34: STEM Degree Completion by Advanced STEM Courses Taken in High School



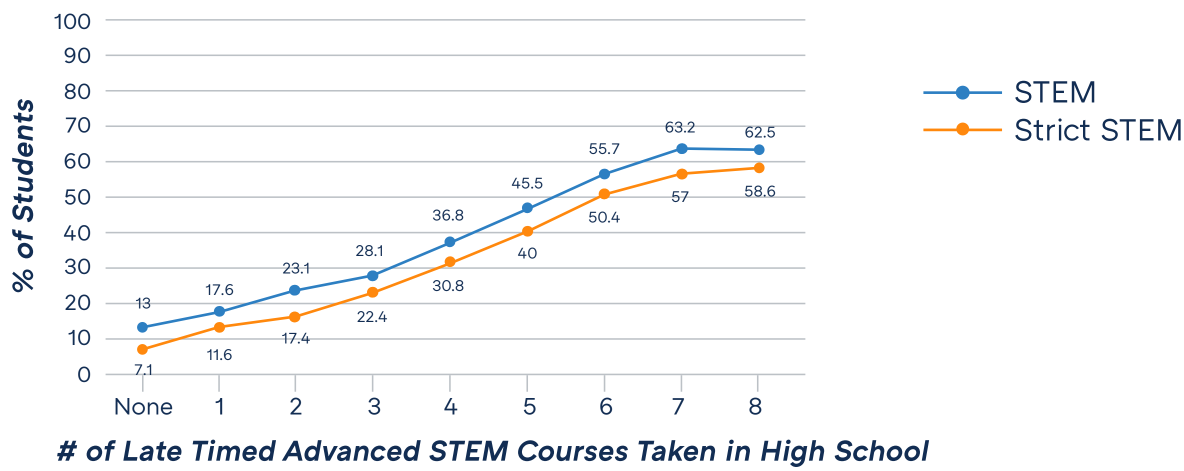
Timing of Advanced STEM Education and Earning a STEM Degree. Figure 35 displays the relationship between early advanced STEM course enrollment and earning a STEM and strict STEM degree. The relationship between early advanced STEM and earning a strict STEM degree was stronger than early advanced STEM and earning a STEM degree. For earning a STEM degree, there was a steady increase from 18.4% for students who did not participate in early advanced STEM to 23.8% for students who enrolled in one course, peaking at 52.4% for students who participated in six early advanced STEM courses. For earning a strict STEM degree, there was a gradual increase from 12.4% for those who did not participate in early advanced STEM to 18% for those who enrolled in one course, peaking at 48.9% for those who participated in six early advanced STEM courses. The difference between proportions was significant for earning a STEM degree ($\chi^2(1, N = 30{,}241) = 1{,}402.12, p < .001$) and for earning a strict STEM degree ($\chi^2(1, N = 30{,}241) = 1{,}742.47, p < .001$) and both associations were moderate ($V = .217$ and $V = .241$, respectively).

FIGURE 35: STEM Degree Completion by Advanced STEM Courses Taken Early in High School



Lastly, Figure 36 portrays the relationship between late advanced STEM enrollment and earning a STEM and strict STEM degree. The association between late advanced STEM enrollment and earning a strict STEM degree is slightly stronger than late advanced STEM enrollment and earning a STEM degree. For earning a STEM degree, there was a steady increase from 13% for students who did not enroll in late advanced STEM to 17.6% for students who enrolled in one course, peaking at 63.2% for students who participated in seven late advanced STEM courses. For earning a strict STEM degree, there was a gradual increase from 7.1% for students who did not enroll in a late advanced STEM course to 11.6% for students who participated in one course, peaking at 58.6% for students who enrolled in eight late advanced STEM courses. The differences between proportions were significant for both earning a STEM degree ($\chi^2(1, N = 30{,}241) = 3{,}056.36, p < .001$) and for earning a strict STEM degree ($\chi^2(1, N = 30{,}241) = 3{,}677.59, p < .001$) and both associations were strong ($V = .322$ and $V = .353$, respectively).

FIGURE 36: STEM Degree Completion by Advanced STEM Courses Taken Late in High School



STEM Employment Availability and Final College Major. Logistic binary regression showed a non-significant relationship between STEM workforce presence and students' final college major upon graduation. This finding suggests that for the cohorts studied, a student's regional STEM workforce may not meaningfully influence his or her decision to pursue and persist with a STEM degree in college.

Main Research Question #2:

Are teacher qualifications/credentials (years of teaching experience and highest degree) and the presence of STEM employment in PA counties associated with the availability of high-quality STEM education in PA schools?

STEM Availability and Sample Descriptive Breakdown

In terms of course availability, descriptive statistics from the 2013-2014 school year showed that the average PA county reported 1,093 available unique courses (excluding special education), spanning all academic disciplines. Special education students and courses were excluded from availability analysis, as most students do not have special education courses available to them. Among non-special education courses, an average of 43% were considered STEM. Thirty-nine percent were considered strict STEM while only four percent classified as lenient STEM. Another 4.4% of all total courses were rigorous STEM, while almost 9% were advanced STEM. Descriptive statistics from the 2014-2015 school year show that on average, PA counties reported 1,056 available non-special education courses from all subject areas. Forty-two percent of these courses were classified as STEM; 38% were strict STEM while 4% were lenient STEM. Almost 5% of available courses were rigorous STEM, and another 9% were advanced STEM. For STEM availability in school year 2015-2016, descriptive statistics revealed that excluding special education courses, counties reported an average of 958 unique courses. Keeping in line with the previous two years of data, 43% of courses were STEM; 38.5% were strict STEM while 4.5% were lenient STEM. Regarding available courses, 6% were rigorous STEM and 10% were advanced STEM. Mean percentages, standard deviations, and ranges for county-wide percentage of rigorous and advanced STEM availability can be found in Table 9.

TABLE 9: Means and Standard Deviations on Rigorous and Advanced STEM Course Availability Percentage across PA Counties by Year

	N	Mean	SD	Range
Rigorous STEM Availability				
2013-2014	67	4.40	2.05	0-11.80
2014-2015	67	4.93	1.95	0-10.80
2015-2016	67	6.06	2.50	0-13.90
Advanced STEM Availability				
2013-2014	67	8.84	3.29	0-14.70
2014-2015	67	8.97	3.11	0-14.50
2015-2016	67	9.82	3.60	0-25.00

For school year 2013-2014, the average PA county reported 1,843 teachers; 72% were female and the other 28% were male. On average, racial and ethnic diversity among counties was low; average ethnicity breakdowns showed that 98% of teachers identified as White. Forty-seven percent of teachers held a Bachelor's degree as their highest degree while another 52% of teachers held a graduate degree. Additionally, teachers averaged 13.91 years of total teaching experience with an average of 12.37 years of experience in their primary district. For school years 2014-2015 and 2015-2016, Table 10 shows that teacher descriptive information was very similar to school year 2013-2014.

TABLE 10: Means and Standard Deviations on Teacher Demographics across PA Counties by Year

		2013-2014			2014-2015			2015-2016		
	N	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Gender										
% Male	67	27.7	2.44	22.3-35.2	27.7	2.40	22.0-36.5	27.9	2.63	22.1-38.3
% Female	67	72.3	2.44	64.8-77.7	72.3	2.40	63.5-78.0	72.1	2.63	61.7-77.9
Ethnicity										
% American Indian/ Alaskan Native	67	0.04	0.07	0-0.4	0.04	0.08	0-0.4	0.04	0.09	0-0.6
% Black or African American	67	1.0	3.02	0-24.1	1.0	2.96	0-23.5	1.0	2.95	0-23.2
% Hispanic	67	0.4	0.6	0-3.4	0.4	0.60	0-3.4	0.4	0.63	0-3.8
% White	67	98.3	3.93	68.6-100	98.2	3.87	69.2-100	98.2	3.93	68.9-100
% Multi-Racial	67	0.1	0.14	0-1.0	0.1	0.15	0-1.1	0.1	0.20	0-1.5
% Asian	67	0.2	0.38	0-2.6	0.2	0.37	0-2.6	0.2	0.36	0-2.4
% Native Hawaiian or other Pacific Islander	67	0.05	0.23	0-1.9	0.05	0.24	0-1.9	0.05	0.26	0-2.1
Experience										
Total years teaching										
% Least experience	67	27.7	4.87	13.0-43.0	26.4	5.24	10.0-43.0	25.5	5.44	9.0-42.0
% Medium experience	67	47.5	4.48	36.0-63.0	46.6	4.51	36.0-62.0	50.2	4.49	40.0-64.0
% Most experience	67	24.7	4.60	14.0-36.0	27.0	4.45	17.0-39.0	24.3	4.24	15.0-37.0
Years teaching in primary district										
% Least experience	67	27.8	5.39	12.0-45.0	26.1	6.02	8.0-43.0	26.2	6.34	10.0-42.0
% Medium experience	67	45.6	5.00	33.0-60.0	49.5	5.28	38.0-65.0	49.6	5.61	38.0-62.0
% Most experience	67	26.7	5.02	18.0-40.0	24.3	4.47	16.0-34.0	24.3	4.45	15.0-35.0
Highest degree earned										
% Bachelor's degree	67	46.8	13.10	18.6-85.8	45.7	13.00	16.1-85.4	44.6	12.20	18.9-84.8
% Graduate degree	67	52.2	13.20	14.0-81.0	53.3	13.10	14.0-83.0	54.2	12.50	15.0-80.3
% Other	67	1.0	0.72	0-3.0	1.03	0.70	0-3.0	1.2	0.78	0-3.31

Department of Labor and Industry (DLI) data showed that in 2014, the average PA county reported 83,548 individuals in the workforce, 10% of whom were STEM workers. Out of this 10%, 3.1% of jobs were considered strict STEM (jobs related to math, science, engineering, IT, etc.) while 6.7% were classified as lenient STEM (health and social sciences, among others). In 2014, counties reported that jobs directly related to science, engineering, mathematics, and IT only comprised 3.3% of the total workforce, while jobs in the health sciences totaled 6%. Table 11 shows similar descriptive findings for the occupational workforce for years 2015 and 2016.

TABLE 11: Means and Standard Deviations on Employment across PA Counties by Year

		2014			2015			2016		
	N	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Overall										
% STEM	67	9.85	4.85	1.8-40.1	10.04	4.88	2.0-40.4	10.06	4.82	2.4-38.9
% Non-STEM	67	90.15	4.85	60.0-98.0	89.96	4.88	60.0-98.0	89.94	4.82	61.0-98.0
STEM										
% Strict STEM	67	0.04	0.07	0-0.4	0.04	0.08	0-0.4	0.04	0.09	0-0.6
% Lenient STEM	67	1.0	3.02	0-24.1	1.0	2.96	0-23.5	1.0	2.95	0-23.2
STEM Sub-Domain										
% Science, Eng., Math, and Info Technology	67	3.28	2.07	0.9-10.3	3.38	2.34	0.3-13.4	3.38	2.16	0.2-9.9
% Health	67	6.14	3.39	0-28.6	6.24	3.10	1.3-25.9	6.29	3.47	0-29.0
% Social Sciences	67	0.26	0.21	0-1.1	0.23	0.22	0-1.0	0.21	0.19	0-1.0
% Architecture										
% Split Sub-Domain										

Note$_1$. Occupational data provided by the Pennsylvania Department of Labor and Industry

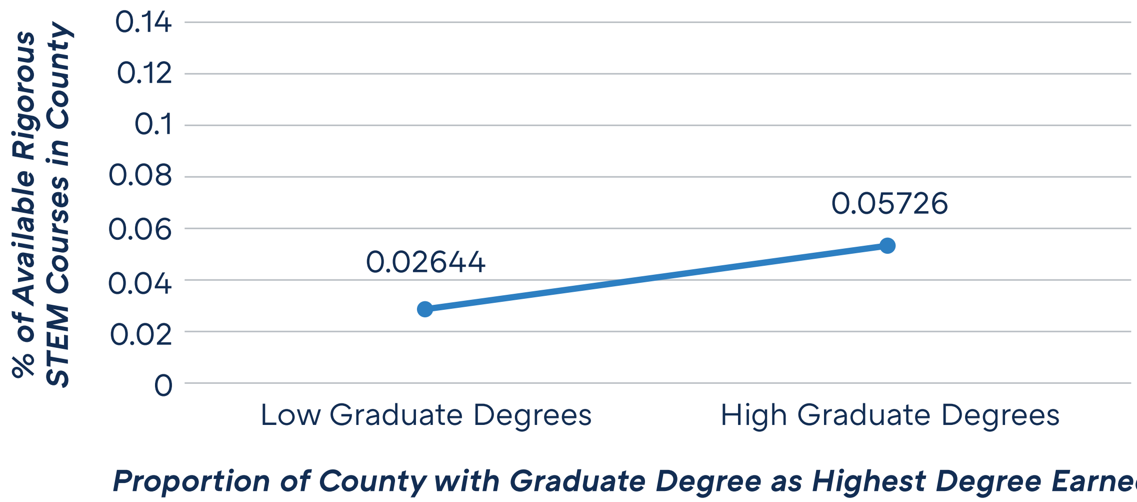
Note$_2$. Architecture and Split Sub-Domain occupational data excluded from table due to small sample sizes

Linear Regression Modeling for STEM Course Availability

Multiple linear regression analysis was used to determine if teacher qualifications (highest degree earned and years teaching) and the strength of the local STEM workforce was significantly associated with the availability of rigorous and advanced STEM courses in PA counties. The dependent variables included county-wide availability of rigorous STEM as defined by PDE (AP, IB, and dual-credit STEM courses) and county-wide availability of all advanced STEM courses (rigorous, honors, and gifted STEM courses).

Final Main Effects Model: 2013-2014 Rigorous STEM Course Availability. The first linear regression analysis examined if the percentage of teachers in a county with a graduate degree was associated with rigorous STEM course availability in school year 2013-2014. Figure 37 depicts the statistically significant effect; a one percent increase in the percentage of teachers who possessed a graduate degree was associated with a near 0.05% increase in rigorous STEM availability (β = .046, p = .014). Table 12 shows that the county-wide percentage of teachers who possessed an advanced degree was associated with almost 9% of the variance in rigorous STEM availability [R^2 = .089, F(1, 65) = 6.36, t = 2.52, p = .014]. All other proposed independent variables were tested for association with rigorous STEM availability (teacher total and primary district experience, teacher gender and ethnicity, school geographic location, STEM employer presence, and strict and lenient STEM employer presence), but none were significant.

FIGURE 37: Association of Teacher Degree Type on the Availability of Rigorous STEM Courses in 2013-2014



Regression Equation: % Available Rigorous STEM Courses in County 2013-2014 = .02 + .046 * GRAD

TABLE 12: Summary Table for Results of Regression Model Predicting Rigorous STEM Course Availability in 2013-2014

	GRAD							
	B	**SE *B***	***t***	***p***	R^2	***F(df)***	***p***	**In**
M								
1	0.05	0.02	2.52	0.014	0.09	6.36(1, 65)	0.014	0.02

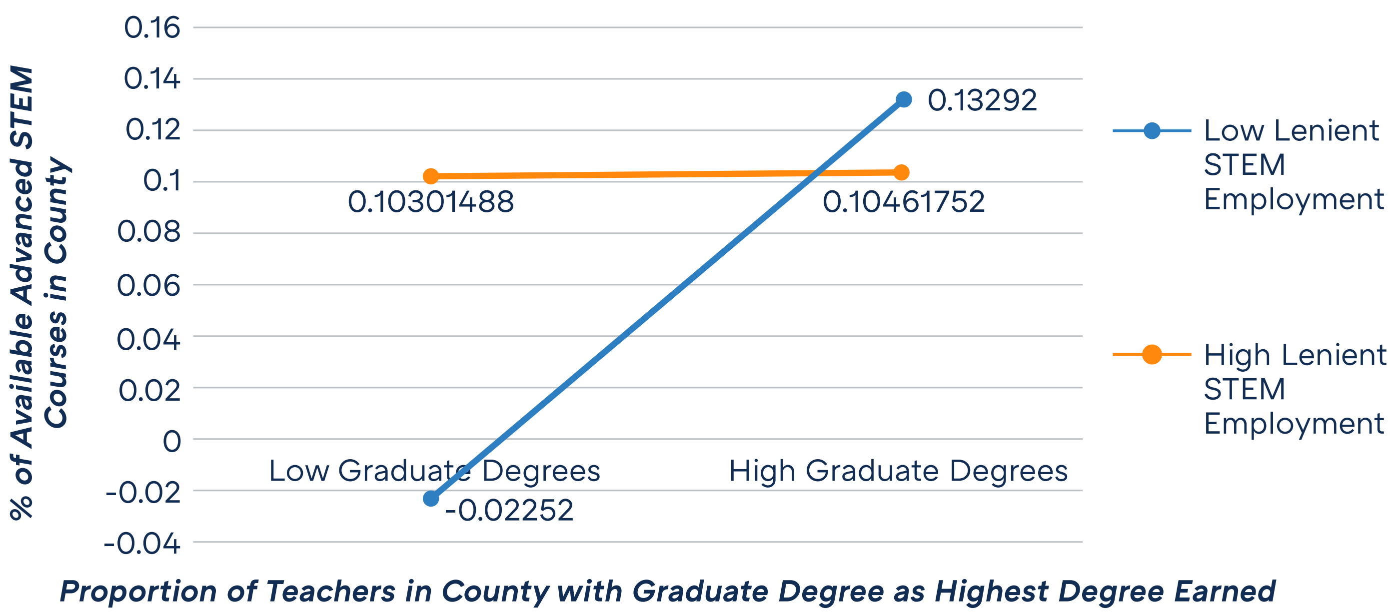
Interaction Effect (Model #3 in Table 13): 2013-2014 Advanced STEM Course Availability
Additionally, regression analysis for 2013-2014 tested the effects of the percentage of teachers with graduate degrees and the percent of lenient STEM employment presence in a county on advanced STEM course availability. Table 13 shows the significant main effects for the percentage of teachers with graduate degrees [R^2 = .20, F(1, 65) = 15.8, p < .001] and the percentage of county-wide lenient STEM employment [R^2 = .086, F(1, 64) = 6.002, p = .017]. The interaction of these two variables, shown by Figure 37, was also tested and found to be significantly associated with the availability of advanced STEM courses [R^2 = .339, F(3, 62) = 10.59, p < .001]. This interaction of the percentage of teachers with graduate degrees and the percent of lenient STEM employment presence is associated with 34% of the variance in PA's 2013-2014 advanced STEM course availability.

This interaction showed that the effect of the proportion of teachers in a county with graduate degrees on advanced STEM availability differs by region; in areas with low lenient STEM employment, a higher number of teachers with graduate degrees is associated with higher advanced STEM availability and a lower percentage of teachers with graduate degrees is associated with lower advanced STEM availability; for counties with high lenient STEM employment, there is very little to no effect based on the percentage of teachers with graduate degrees. Other variables, including teacher total and primary district experience, teacher ethnicity and gender, school geographic location, and all forms of STEM employer presence were tested for association with advanced STEM availability in 2013-2014, but none were found to be statistically significant.

Interaction Effect (Model #6 in Table 13): 2013-2014 Advanced STEM Course Availability. The final significant model for the 2013-2014 school year tested a statistical interaction between the percentage of teachers with graduate degrees and the percentage of health science jobs in PA counties. Results in Table 13 show that both the main effect of teachers with graduate degrees [$R^2 = .196$, $F(1, 65) = 15.8$, $p < .001$] and the main effect for the percentage of county-wide health STEM employment [$R^2 = .06$, $F(1, 64) = 4.1$, $p = .046$] were significantly associated with advanced STEM availability. The interaction of these two variables (see Figure 38) was also significantly associated with the availability of advanced STEM courses in PA counties; further, 34% of the variance in advanced STEM course availability is associated with variation in the interaction between the percentage of teachers who have graduate degrees and the percentage of health STEM jobs in a county [$R^2 = .340$, $F(3, 62) = 10$, $p < .001$].

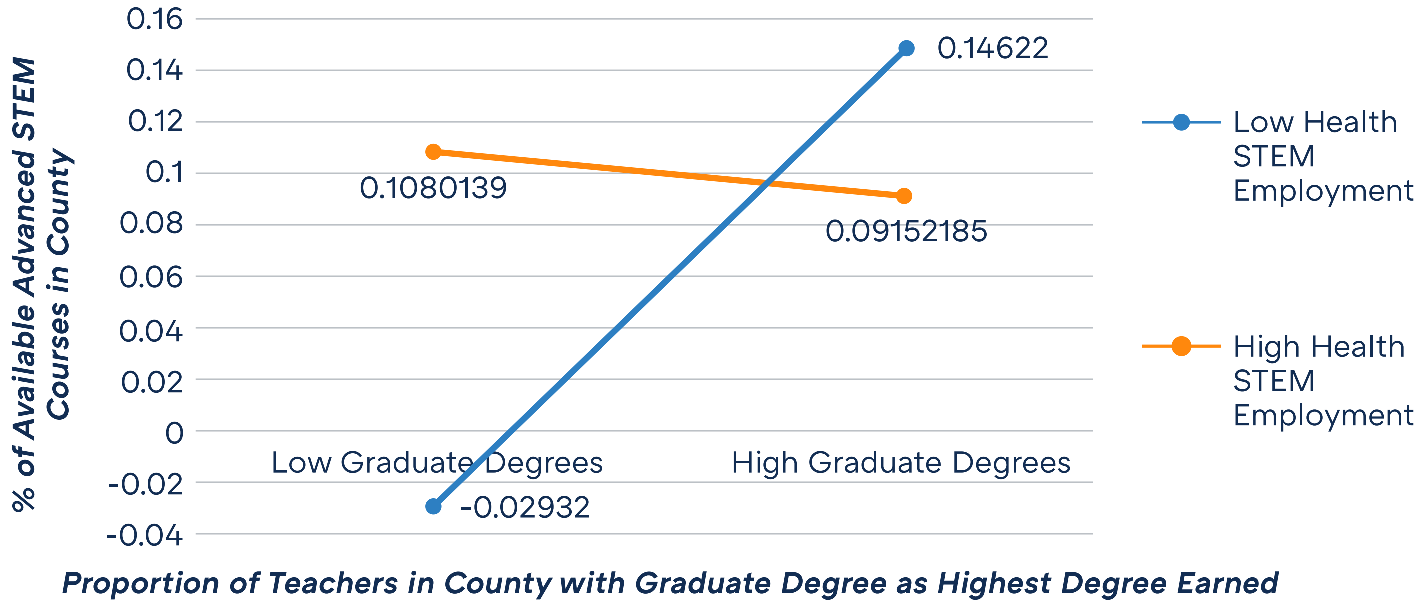
In counties with low health STEM employment, a high number of teachers with graduate degrees is associated with a higher amount of advanced STEM course availability and a lower percentage of teachers with graduate degrees was associated with lower advanced STEM availability; similar to the first interaction model, this effect is not observed for counties with high health STEM employment. The overall model similarity between both interaction models may be influenced by the high degree of association between health and lenient STEM employment ($r = .98$), suggesting that health STEM employment constitutes most of lenient STEM employment. All other proposed variables were tested for associations with outcome variables, but none were statistically significant.

FIGURE 38: Association between Lenient STEM Employment and Teacher Degree Type on the Availability of Advanced STEM Courses in 2013-2014



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

FIGURE 39: Association between Health STEM Employment and Teacher Degree Type on the Availability of Advanced STEM Courses in 2013-2014



Regression Equation: % Available Advanced STEM Courses in County 2013-2014= -.066 + .262 * GRAD + 1.868 * HEALTH – 3.017 * (GRAD * HEALTH)

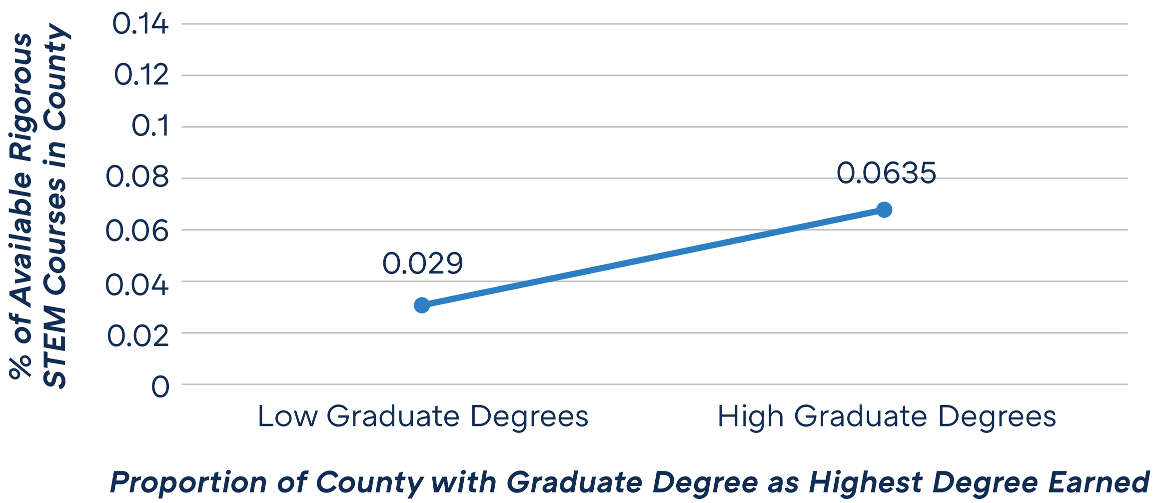
TABLE 13: Summary Table for Results of Multiple Regression Models Predicting Advanced STEM Course Availability in 2013-2014

	GRAD			LENIENT			HEALTH			GRAD x LENIENT			GRAD x HEALTH						
	B	SE *B*	*t*	*B*	SE *B*	*t*	*B*	SE *B*	*t*	*B*	SE *B*	*t*	*B*	SE *B*	*t*	R^2	*F (df)*	*p*	ln
M																			
1	0.11	0.03	3.98****													.20	15.8 (1, 65)	.0001	0.031
2				0.46	0.19	2.45*										.09	6.0 (1, 64)	.017	0.059
3	0.23	0.06	3.97****	1.46	0.46	3.18**				-2.13	0.91	-2.325*				.34	10.6 (3, 62)	.0001	-0.055
4	0.11	0.03	3.98****													.20	15.8 (1, 65)	.0001	0.031
5							0.42	0.21	2.03*							.06	4.1 (1, 64)	.046	0.064
6	0.26	0.06	4.34****				1.87	0.55	3.40***				-3.0	1.01	-2.76***	.34	10 (3, 62)	.0001	-0.066

Note. * $p < .05$; ** $p < .01$; *** $p < .001$; **** $p < .0001$

Final Main Effects Model: 2014-2015 Rigorous STEM Availability. Figure 40 shows that the percentage of teachers with graduate degrees was found to be significantly associated with county-wide rigorous STEM availability during the 2014-2015 school year. Displayed in Table 14, the percentage of teachers who had graduate degrees was associated with 11% of the variance in rigorous STEM course availability [R^2 = .114, $F(1,65)$ = 8.40, t = 2.90, p = .005]. A one percent increase in the county-wide percentage of teachers who possessed graduate degrees was associated with a 0.05% increase in the availability of rigorous STEM courses (β = .05, p = .005). All variables previously discussed were examined and none were found to be statistically significant.

FIGURE 40: Association of Teacher Degree Type on the Availability of Rigorous STEM Courses in 2014-2015



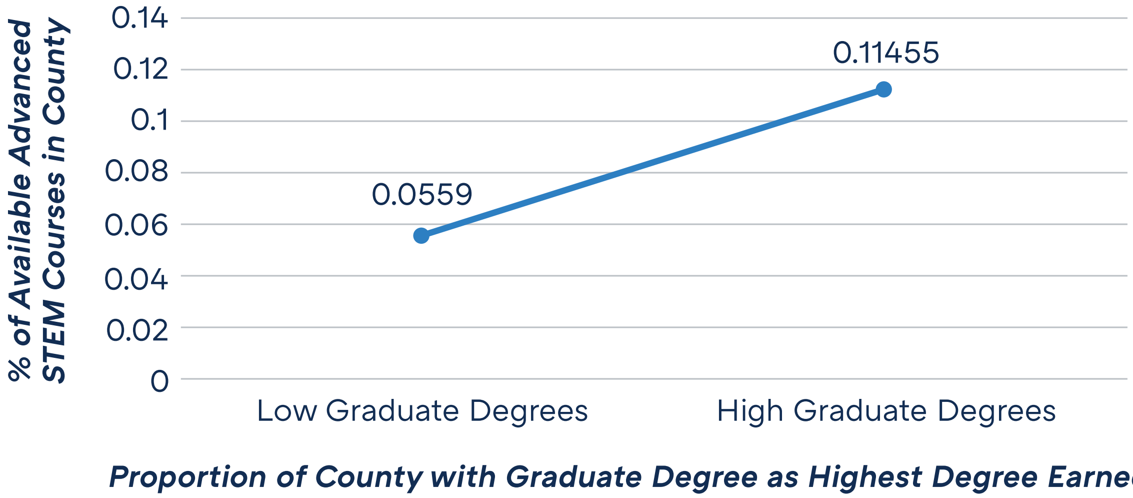
Regression Equation: % Available Rigorous STEM Courses in County 2014-2015 = .022 + .05 * GRAD

TABLE 14: Summary Table for Results of Regression Model Predicting Rigorous STEM Course Availability in 2014-2015

	GRAD							
	B	SE *B*	*t*	*p*	R^2	*F(df)*	*p*	In
M								
1	0.05	0.02	2.90	0.005	0.11	8.4(1,65)	0.005	0.02

Final Main Effects Model: 2014-2015 Advanced STEM Availability. Figure 41 shows that the county-wide percentage of teachers with graduate degrees was significantly associated with the availability of advanced STEM courses during the 2014-2015 school year. Displayed by Table 15, the percentage of teachers who possessed graduate degrees was associated with almost 13% of the variance in the county-wide availability of advanced STEM courses [R^2 = .129, F(1, 65) = 9.60, t = 3.10 p = .003]. A one percent increase in the percentage of teachers with graduate degrees was associated with an almost .09% increase in county-wide availability of advanced STEM courses (β = .085, p = .003). No other variables were found to be significantly associated with availability of advanced STEM courses.

FIGURE 41: Association of Teacher Degree Type on the Availability of Advanced STEM Courses in 2014-2015



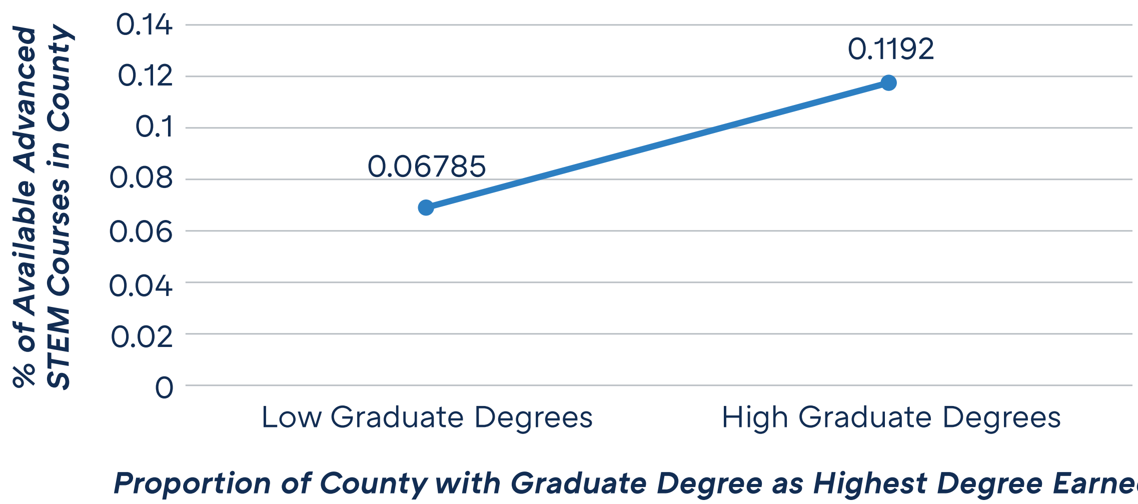
Regression Equation: % Available Advanced STEM Courses in County 2014-2015 = .044 + .085 * GRAD

TABLE 15: Summary Table for Results of Multiple Regression Model Predicting Advanced STEM Course Availability in 2014-2015

	GRAD							
	B	SE *B*	*t*	*p*	R^2	*F(df)*	*p*	In
M								
1	0.09	0.03	3.1	0.003	0.13	9.6(1, 65)	0.003	0.04

Final Main Effects Model: 2015-2016 Advanced STEM Course Availability. While no variables tested were found to be significantly associated with the availability of rigorous STEM in 2015-2016, Figure 42 and Table 16 show that the percentage of teachers with graduate degrees was significantly associated with the county-wide availability of advanced STEM courses [$F(1,65) = 5.19$, $t = 2.28$, $p = .026$]. A one percent increase in the percentage of teachers in a county who held graduate degrees was associated with an .08% difference in advanced STEM availability ($\beta = .079$, $p = .026$), but is associated with a very small amount of variance ($R^2 = .074$). All other variables of interest were tested, but none were found to be statistically significant.

FIGURE 42: Association of Teacher Degree Type on the Availability of Advanced STEM Courses in 2015-2016



Regression Equation: % Available Advanced STEM Courses in County 2015-2016 = .056 + .079 * GRAD

TABLE 16: Summary Table for Results of Regression Model Predicting Advanced STEM Course Availability in 2015-2016

	GRAD							
	B	SE *B*	*t*	*p*	R^2	*F(df)*	*p*	In
M								
1	0.08	0.03	2.28	0.026	0.074	5.2(1,65)	0.026	0.06

Sub-Question #4:
How is STEM and strict STEM course availability related to STEM and strict STEM course enrollment during high school?

To examine the relationship between STEM course availability and STEM course enrollment, all LEAs were assigned a status of low STEM availability, medium STEM availability, or high STEM availability based on frequency distributions among all LEAs. A one-way between subjects analysis of variance (ANOVA) was used to examine differences between means in STEM enrollment by STEM availability status group.

Although Fisher's Least Significant Difference (LSD) post hoc comparisons showed a statistically significant effect for STEM course availability on total STEM enrollment, the difference in means was minimal with a mean enrollment of 11.21 STEM courses for students in LEAs with high STEM availability compared to a mean of 10.3 for students in LEAs with low STEM availability [$F(2, 286{,}272) = 3{,}349$, $p < .001$]. Similarly, the availability of strict STEM courses was significantly associated with strict STEM enrollment [$F(2, 288{,}353) = 2{,}357.97$, $p < .001$], with minimal differences between means (10.01 for high availability versus 9.34 for low availability).

Given the minimal differences in enrollment means based on STEM and strict STEM course availability status, additional ANOVAs were used to examine how the effects of enrollment in STEM and strict STEM may be associated with STEM and strict STEM availability. Analyses showed a statistically significant effect for STEM enrollment on STEM availability [$F(9, 286{,}265) = 1{,}048.56$, $p < .001$] and for strict STEM enrollment on strict STEM availability, [$F(9, 203{,}190.13) = 802.82$, $p < .001$]. LSD post hoc analyses showed that each category of STEM course enrollment was associated with significantly higher levels of availability than the preceding category. For example, students who enrolled in seven or eight STEM courses had significantly more STEM courses available to them ($M = 41.02$, $SD = 17.61$) than students who enrolled in five or six STEM courses ($M = 36.66$, $SD = 17.54$) and students who participated in 11 or 12 STEM courses had significantly higher STEM availability ($M = 47.61$, $SD = 17.41$) than students who participated in nine or ten STEM courses ($M = 44.79$, $SD = 17.58$). Additionally, students who participated in seven or eight strict STEM classes had higher strict STEM availability ($M = 39.34$, $SD = 15.91$) than students who participated in five or six strict STEM courses ($M = 34.35$, $SD = 36$) and students who enrolled in 11 or 12 strict STEM courses had significantly higher strict STEM course availability ($M = 43.56$, $SD = 15.86$) than students who enrolled in nine or ten strict STEM courses ($M = 42.27$, $SD = 16.04$). Although Levene's Test of Homogeneity of Variance was violated in both analyses ($p < .001$), a Kruskal-Wallis non-parametric test supported the overall significant effects ($H = 8{,}802.45$, $p < .001$, $df = 9$ & $H = 6{,}808.39$, $p < .001$, $df = 9$). Taken together, these findings show that while increases in STEM course availability are not necessarily associated with meaningful increases in STEM course enrollment, students with greater STEM enrollment tend to also have more STEM courses available to them.

Sub-Question #5:
Are minority groups significantly underrepresented in STEM opportunities in PA?

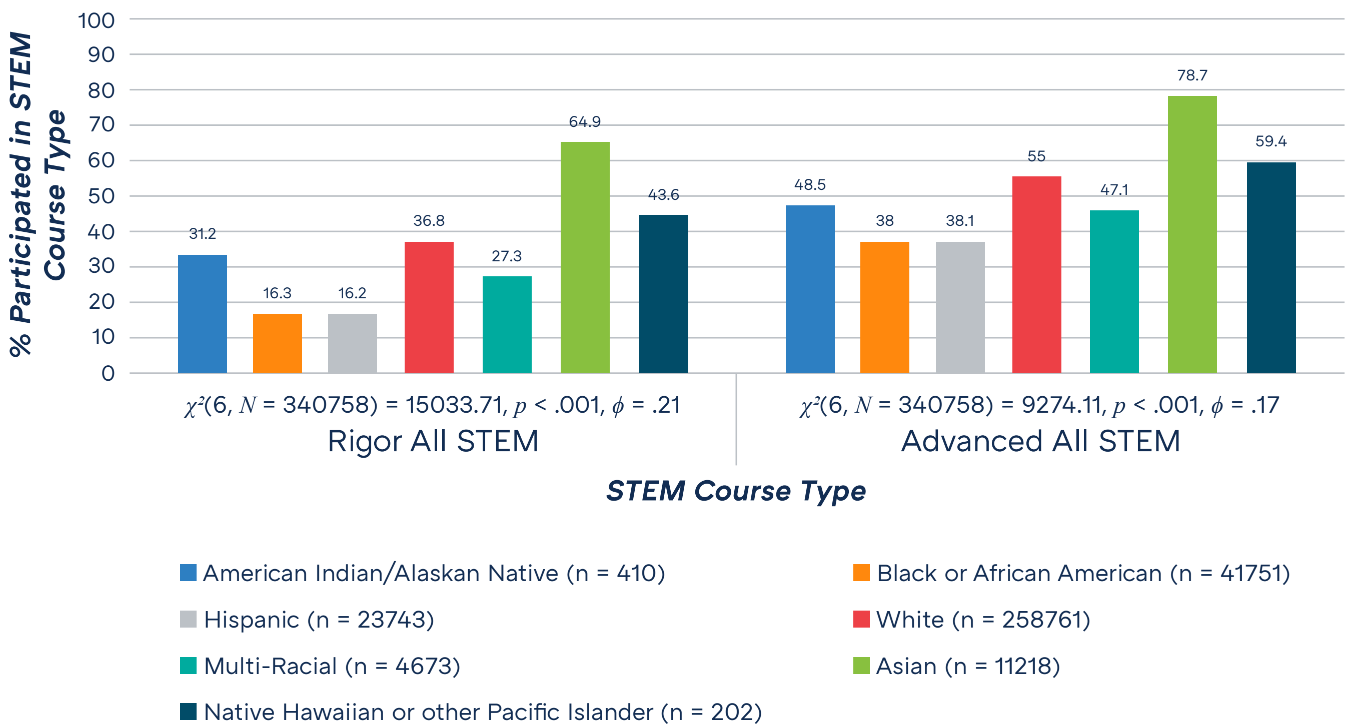
Taking cues from the variety of literature that has reported disparities in representation for various demographic groups in STEM, the present study sought to determine if such disparities existed in PA educational opportunities. The subsequent analyses focused on the following groups often considered underrepresented in STEM opportunities: women, ethnic/racial minority groups, and students considered historically underperforming (special education, EL, and economically disadvantaged students).

STEM Course-Taking in High School

Pearson chi-square analysis highlighted differences between males and females in STEM course-taking patterns. For instance, 36.6% of females enrolled in one or more rigorous STEM course, while 30.8% of males did. This represents a significant difference between proportions ($\chi^2(1, N = 340{,}758) = 1{,}255.91$, $p < .001$) and the association between gender and rigorous STEM enrollment was small ($\phi = .061$). Further, 56.2% of females participated in one or more advanced STEM courses, compared to 48.6% of males. This difference in proportions was also significant, $\chi^2(1, N = 340{,}758) = 1{,}993.71$, $p < .001$, indicating a small association between gender and enrollment in advanced STEM courses ($\phi = -.076$).

Student race/ethnicity was also tested for associations with STEM enrollment. Figure 43 shows that 16.2% of Hispanic students enrolled in one or more rigorous STEM courses and 16.3% of African American or Black students enrolled in at least one rigorous STEM course. In comparison, 36.8% of White students and 64.9% of Asian students participated in at least one rigorous STEM course. For advanced STEM enrollment, results showed that 38% of both Hispanic and African American or Black students enrolled in one or more advanced STEM courses, while 55% and 78.7% of White and Asian students enrolled in at least one advanced course, respectively. The differences between proportions were significant for both rigorous STEM enrollment ($\chi^2(6, N = 340{,}758) = 15{,}033.71, p < .001$) and for advanced STEM enrollment ($\chi^2(6, N = 340{,}758) = 9{,}274.11, p < .001$), with moderate and small associations ($\phi = .21$ and $\phi = .165$, respectively).

FIGURE 43: Rigorous and Advanced STEM High School Course Participation by Ethnicity



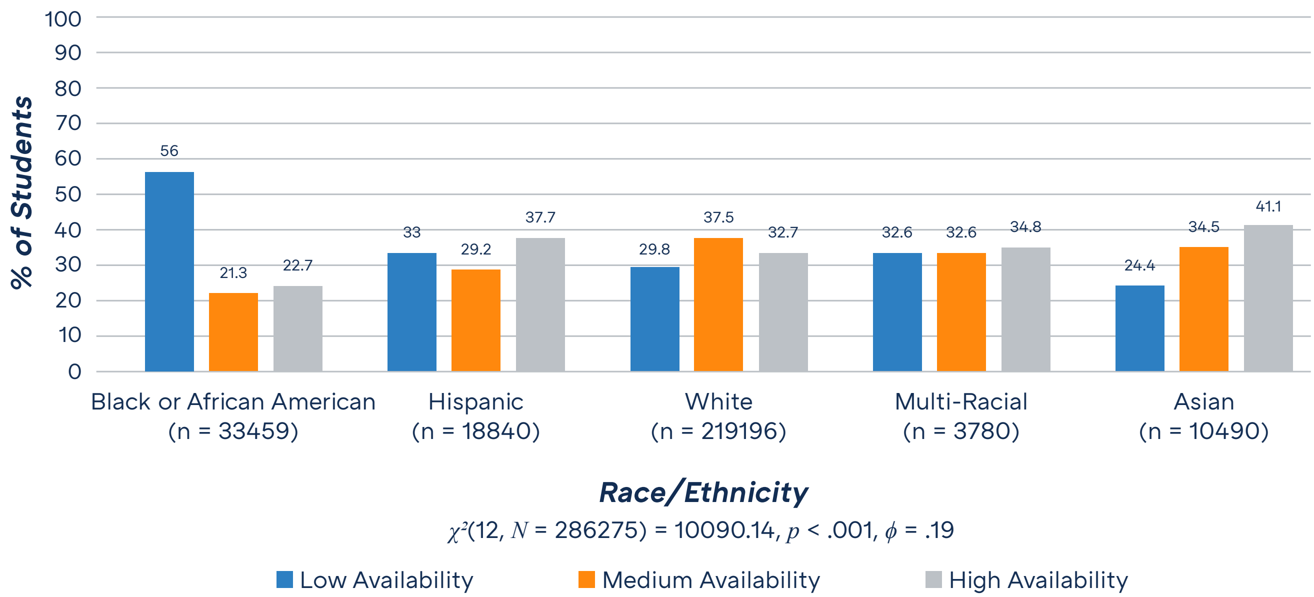
For historically underperforming students, results showed a 17.1% participation rate in at least one rigorous STEM course, compared to 45.2% for non-historically underperforming students. There was a significant difference between proportions ($\chi^2(1, N = 340{,}758) = 29{,}180.14, p < .001$) and the association between historically underperforming status and rigorous STEM enrollment was moderate ($\phi = -.293$). Historically underperforming status was also associated with advanced STEM enrollment, as 34.7% of historically underperforming students participated in one or more advanced STEM courses while 64.8% of non-historically underperforming students did the same. This difference between proportions was also significant, ($\chi^2(1, N = 340{,}758) = 30{,}122.11, p < .001$), showing a moderate relationship between historically underperforming status and advanced STEM enrollment ($\phi = -.297$).

STEM Course Availability

To examine STEM availability, LEAs were assigned a status as either low strict/STEM availability, medium strict/STEM availability, and high strict/STEM availability based on frequency distributions. Figure 44 depicts that 29.8% of White students were enrolled at LEAs with low STEM availability compared to 56% of Black or African American students. Also, 41.1% of Asian students were enrolled at LEAs with high STEM availability. Results showed similar findings for strict STEM availability; 57.7% of Black or African American students were enrolled at low strict STEM available schools, compared to 32.7% of White students. The differences between proportions were significant for both the availability of STEM (χ^2(12,

N = 286,275) = 10,090.14, $p < .001$) and strict STEM (χ^2(12, N = 288,356) = 9,630.65, $p < .001$) and both associations were small (ϕ = .188 and ϕ = .183, respectively).

FIGURE 44: STEM Course Availability Classification (Low, Medium, High) by Race/Ethnicity

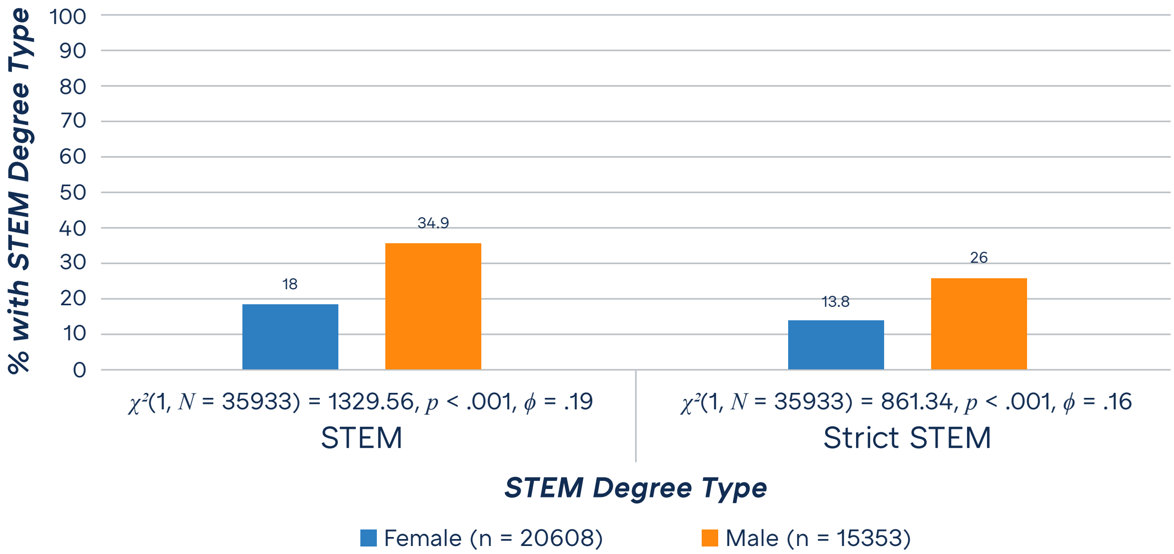


Results showed a similar situation for historically underperforming students; almost 44% were enrolled at schools with low STEM availability, compared to 27.8% of non-historically underperforming students. Findings were similar for strict STEM availability, as 46.1% of historically underperforming students attended schools with low strict STEM availability, compared to 33.1% of non-historically underperforming students. The differences between proportions were significant for both STEM availability (χ^2(2, N = 286,275) = 7,540.13, $p < .001$) and strict STEM availability (χ^2(2, N = 288,356) = 6,771.77, $p < .001$) and both associations were small (ϕ = .162 and ϕ = .153, respectively).

College Major Upon Graduation

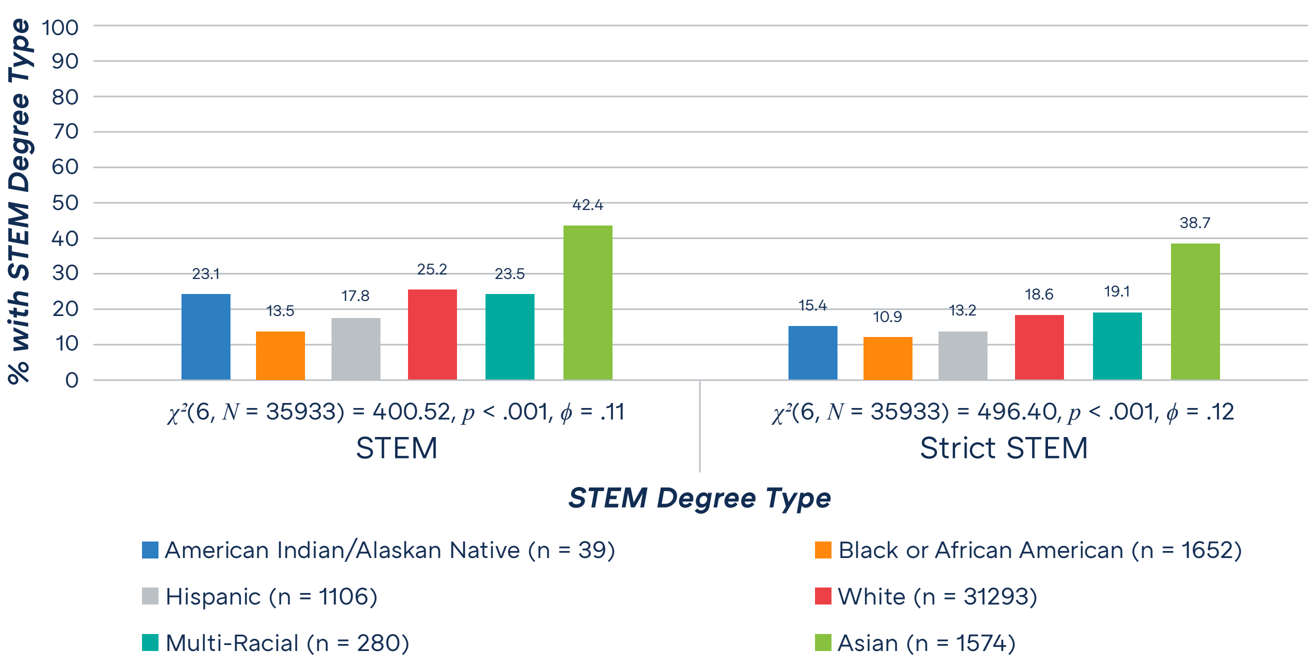
Among students who could be tracked to postsecondary graduation, regardless of cohort, it was found that earning a STEM degree varied by both gender and ethnicity. Figure 45 shows that among all males who graduated, 34.9% earned a STEM degree compared to 18% of female graduates. Additionally, 26% of males earned strict STEM degrees compared to 13.8% of females. Differences between proportions were significant for both earning a STEM degree (χ^2(1, N = 35,933) = 1,329.56, $p < .001$) and for earning a strict STEM degree (χ^2(1, N = 35,933) = 861.34, $p < .001$) and both associations were small (ϕ = .192 and ϕ = .155, respectively).

FIGURE 45: STEM Degree Completion by Gender



Graduation from college with a STEM degree also varied by student racial/ethnic identity. Figure 46 displays results which show that 13.5% of Black or African American students graduated with a STEM degree, compared to 17.8% of Hispanic students, 25.2% of White students, and 42.4% of Asian students. Additionally, 10.9% of Black or African American students earned a strict STEM degree, compared to 13.2% of Hispanic students, 18.6% of White students, and 38.7% of Asian students. The differences between proportions were significant for both earning a STEM degree ($\chi^2(6, N = 35{,}933) = 400.52, p < .001$) and for earning a strict STEM degree ($\chi^2(6, N = 35{,}933) = 496.4, p < .001$) and both associations were small ($\phi = .106$ and $\phi = .118$, respectively).

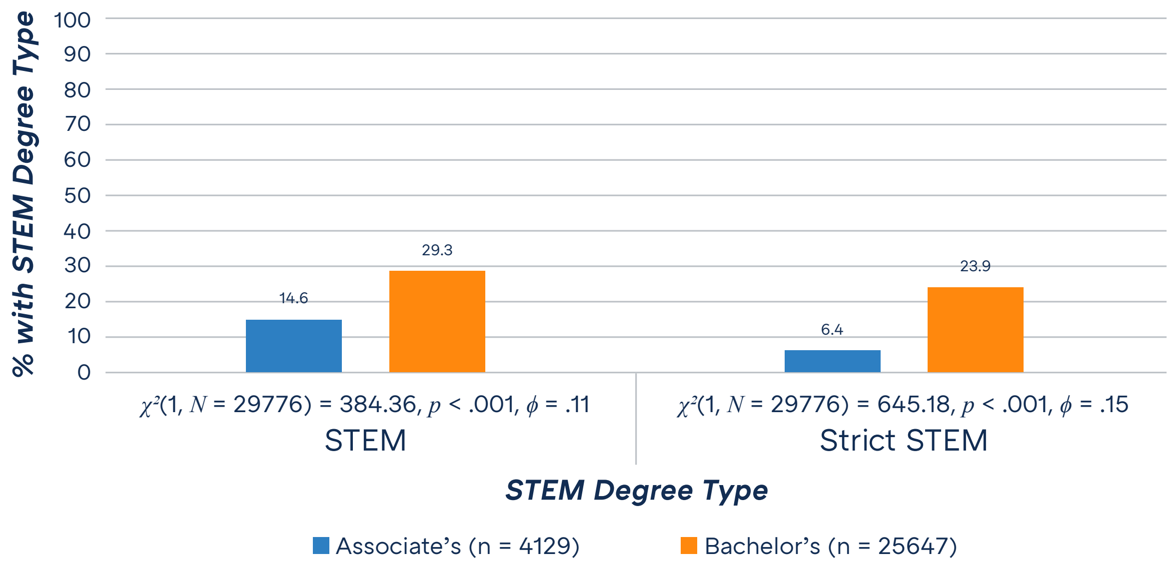
FIGURE 46: STEM Degree Completion by Ethnicity



Note: The Native Hawaiian/Pacific Islander student group was excluded from analysis due to a small cell size of less than 20 students

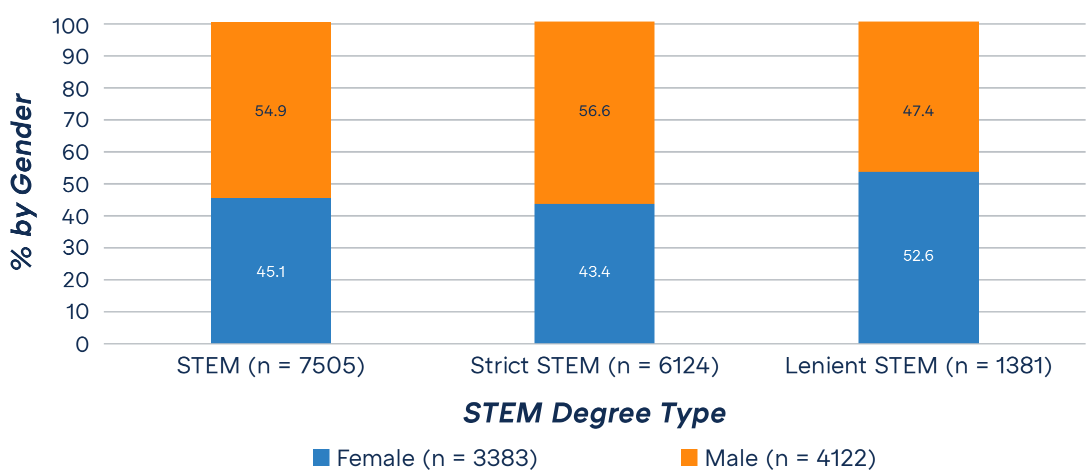
Figure 47 shows how degree type (Bachelor's or Associate's) varied by the degree's status as STEM or non-STEM. Specifically, 29.3% of earned Bachelor's degrees were STEM and the other 70.7% were non-STEM. Of all earned Associate's degrees, 14.6% were STEM and 85.4% were non-STEM. Of all Bachelor's degrees, 23.9% were strict STEM and only 6.4% of Associate's degrees were strict STEM. The differences between proportions were significant for earning a STEM degree ($\chi^2(1, N = 29{,}776) = 384.36, p < .001$) and for earning a strict STEM degree ($\chi^2(1, N = 29{,}776) = 645.18, p < .001$) and both associations were small ($\phi = .114$ and $\phi = .147$, respectively).

FIGURE 47: STEM Degree Completion by Degree Type



While 35% of male and 18% of female graduates earned STEM degrees, there was also a statistically significant difference between the proportions for gender among STEM graduates ($\chi^2(1, N = 35{,}933) = 1{,}329.52, p < .001$) which showed a small association ($\phi = .192$). Among the 7,505 students who earned STEM Bachelor's degrees, 45% were female and 55% were male. This 10-percentage point disparity between genders is lower than the national difference of 28% (NCES, 2019). Figure 48 shows that compared to STEM degree completion, slightly fewer strict STEM Bachelor's degrees went to females (43.4%) but slightly more lenient Bachelor's STEM degrees went to females (52.6%).

FIGURE 48: STEM Bachelor's Degree Completion Broken Down by Gender



Racial/ethnic identity and historically underperforming status was also tied to STEM degree completion. Regarding race and ethnicity, 13.5% of Black or African American graduates completed STEM degrees, compared to 17.8% of Hispanic students, 25.2% of White students, and 42.4% of Asian students. These differences in proportions were significant, $\chi^2(6, N = 35{,}933) = 378.55$, $p < .001$), however, the association was small ($\phi = .106$). For PA students who graduated within four years of high school graduation, among the 7,505 earned STEM degrees, 87% went to White students, 8% went to Asian students, 2.3% were awarded to Black or African American students, and almost 2% went to Hispanic students.

Lastly, results showed that 14.5% of students in the historically underperforming group earned a STEM degree, while almost 21% of students in the non-historically underperforming group earned a STEM degree. This difference in proportions was significant, $\chi^2(1, N = 35{,}933) = 177.47$, $p < .001$), but the association between historically underperforming status and STEM degree attainment was very small ($\phi = -.070$).

Discussion

Researchers, policymakers, and educators generally agree that a high-quality STEM education is essential for the future of Pennsylvania and the United States. While students enter the STEM pipeline from their earliest days in school, previous research has suggested that decisions to enroll in STEM courses during high school are associated with various educational outcomes, including high school and college graduation and major choice (Sadler, Sonnert, & Hazari, 2014; Shaw & Barbuti, 2010). Further, many have reported a disparity in representation in STEM opportunities throughout the pipeline for certain groups such as women, African American, and Hispanic students (Graham, Frederick, Byards-Winston, Hunter, & Handelsman, 2013; Tyson, Lee, Borman, & Hanson, 2007). Results from research questions which addressed these topics will be examined to shed light on the importance of STEM educational opportunities in PA.

Main Research Question #1:
Are STEM course-taking patterns in high school associated with postsecondary trajectory, as defined by college enrollment, persistence, retention, and graduation?

To understand how high school STEM course-taking was associated with postsecondary outcomes, logistic binary regression and multiple linear-by-linear chi-squares were analyzed and interpreted. Results generally suggested that higher enrollment in any type of STEM course (STEM, strict STEM, rigorous STEM, rigorous strict STEM, and advanced STEM) during high school was associated with increases in high school graduation rates, college enrollment, persistence and retention throughout college, and college graduation. Of note was the finding that enrollment in just one rigorous STEM course during high school was associated with a 98.5% high school graduation rate. Additionally, higher rates of rigorous STEM course-taking were associated with increased college graduation rates; in fact, college graduation rates for students who enrolled in five rigorous STEM courses were nearly double those of students who did not participate in rigorous STEM courses during high school. Rigorous and advanced STEM course-taking was moderately or strongly associated with college enrollment, persistence, and graduation.

Results from the present study are in line with findings from previous studies which have documented that STEM course-taking in high school has long-term benefits for future educational success (Ackerman, Kanfer, & Calderwood, 2013; Maltese & Tai, 2010; Shaw & Barbuti, 2010). The present findings suggest that increased enrollment in both a broad and more narrow conception of STEM is associated with better postsecondary outcomes, regardless of performance. This may be partly attributed to the variety of skills and problem-solving skills that students can potentially learn while enrolled in STEM courses (Barak & Assal, 2016).

Main Research Question #2:
Are teacher qualifications/credentials (years of teaching experience and highest degree) and the presence of STEM employment in PA counties associated with the availability of high-quality STEM education in PA schools?

Although various researchers have studied how teacher quality is related to student achievement outcomes (Chingos & Peterson, 2011; Bottia, Stearns, Mickelson, Moller, & Valentino, 2015; Henry, Fortner, & Bastian 2012), the authors know of no study to date which has investigated how teacher qualifications might be related to STEM course availability. Additionally, while literature discussing the national and state-level STEM workforce is extensive (ECS, 2019; John, Chen, Navaee, & Gao, 2018), the authors know of no research to date which has studied how the status of a regional STEM workforce might influence regional STEM course availability.

While linear regression results did not show significant main effects of teacher experience, gender, ethnicity, LEA geographical location, or STEM employment presence on rigorous or advanced STEM availability for any year, significant main effects for the percentage of teachers with graduate degrees were found. Specifically, a higher county-wide percentage of teachers with graduate degrees was associated with a higher amount of county-wide rigorous STEM availability for school years 2013-2014 and 2014-2015. For the availability of advanced STEM courses, this association was found for all school years. Further, an interaction effect was found for county-wide advanced STEM availability in school year 2013-2014; results showed that for counties with low lenient STEM employment, the availability of advanced STEM courses fluctuates with the percentage of teachers who possess graduate degrees. Specifically, in counties with low lenient STEM employment, a low percentage of teachers with graduate degrees was associated with lower advanced STEM course availability, while a higher percentage of teachers with graduate degrees was associated with higher advanced STEM availability. Notably, this interaction was associated with 34% of the variance in advanced STEM availability for school year 2013-2014. For counties with high lenient STEM employment, there was no meaningful difference between advanced STEM availability, regardless of teachers' highest degrees.

It is important to note that a similar effect was observed for the interaction between teachers with graduate degrees and county-wide health STEM employment. This overlap may be influenced by the high degree of correlation between health STEM employment and lenient STEM employment ($r = .98$). This suggests that health STEM employment comprised the majority of lenient STEM employment, implying that this complex interaction effect is mostly due to the role of health STEM employment in a county.

Results suggest that more highly educated teachers in a geographical region may be linked to an increase in advanced STEM course availability. This may be related to teacher confidence and preparation to teach STEM; Education Trust-West (2016) found that low numbers (between 25 and 45%) of Californian elementary and secondary teachers felt prepared to teach STEM subjects such as physics and math. As teachers feel more confident in their education and preparedness to teach STEM, they may offer to teach more advanced STEM courses, increasing the number of high-quality STEM courses available to students. While identifying a root cause of the discovered interaction effect is difficult, the finding that health (and lenient) STEM occupational presence interacts with teacher highest degree suggests that advanced STEM course availability is associated with a variety of factors from multiple areas. Additionally, the current results imply that specific types of STEM occupational presence may have a role in influencing availability of advanced STEM courses in schools.

Sub-Question #1:
What is the description and breakdown of student cohort populations by year?

Comparisons between cohort groups did not show any meaningful differences between gender, racial/ethnic groups, or other demographic variables. When cohort size was reduced for enrollment analysis to only include students with all years of course data, representation of certain URM groups (Black or African American and Hispanic) decreased. However, these decreased totals are still reflective of PA census data for 2010 (U.S. Census Bureau, 2010), indicating that student cohorts were representative of the PA population. Therefore, analysis for outcome variables were conducted in a file containing all three cohorts.

Sub-Question #2:
Are postsecondary trajectories differentially affected by advanced STEM courses taken early in high school as opposed to later in high school?

While early exposure to STEM content has been prioritized by previous literature (McClure et al., 2017; Tippett & Milford, 2017), there has been comparatively little focus on determining if STEM enrollment at various times in high school may influence postsecondary enrollment. The current study found that higher enrollment in both early (freshman or sophomore year) and late (junior or senior year) advanced STEM was associated with positive outcomes, including high school graduation, college enrollment, persistence and retention, college graduation, and graduating with a STEM degree.

While early and late timing of advanced STEM courses were both positively associated with most outcomes, late timing of advanced STEM consistently showed a higher association than early timing of advanced STEM courses for all outcome variables. This finding implies that while enrollment in one or more advanced STEM courses during freshman or sophomore year is associated with positive outcomes, enrollment in advanced STEM during junior or senior year has a stronger connection to high school graduation, college enrollment, retention, persistence, and graduation. As students enter their final two years of high school, it is possible that they become more deliberate in their course-taking behaviors and choose to enroll in advanced STEM courses to become better prepared for postsecondary study. Higher student enrollment in early timed rigorous STEM courses would have allowed for comparisons between early and late timed rigorous strict/STEM courses, potentially clarifying this finding.

Sub-Question #3:

Are factors related to STEM education and the STEM employment availability in a student's county associated with his or her college major upon graduation?

Results suggest a significant positive association between all forms of STEM course-taking in high school (STEM, strict STEM, rigorous STEM, rigorous strict STEM, and advanced STEM) and college graduation with a STEM degree. Specifically, a strong association between advanced STEM course-taking and STEM degree completion showed that steady increases in advanced STEM enrollment during high school were associated with steady increases in earning both a strict STEM degree and a general STEM degree. Gradual increases in rigorous STEM enrollment were also associated with increases in graduating with a STEM major; approximately 67% of students who enrolled in more than five rigorous STEM courses graduated with a STEM degree. All types of advanced STEM course-taking were strongly associated with earning both a STEM degree and a strict STEM degree, indicating that enrollment in these courses may help prepare students for studying STEM topics in college.

The present findings lend support to findings from previous research which has linked high school enrollment in STEM courses with a student's decision to choose and persist with a STEM major in college (Sadler, Sonnert, & Hazari, 2014; Wang, 2013). As over half of college-educated STEM students join the STEM workforce (Pew Research Center, 2018), these results suggest that higher advanced STEM enrollment in high school is related to higher STEM degree attainment, which ultimately produces more workers for various STEM fields.

To the best of the authors' knowledge, no study to date has investigated how the nature of a region's STEM workforce might influence students who reside in that region to choose, and ultimately graduate with, a STEM degree. Logistic binary regression failed to show any significant relationships between county-wide STEM employer presence and a student's decision to earn a STEM degree. There are many factors that influence a student's decision to select and persist with a college major and it is possible that the size of a student's local STEM workforce does not significantly contribute to this decision. Alternatively, as 35% of the national STEM workforce does not hold a Bachelor's degree (Pew Research Center, 2018), a significant portion of students who desire to enter the STEM workforce immediately after high school may do so without attending college. Additional research, at the state and national level, is required to understand if information related to the STEM workforce is related to student major choice and major upon graduation.

Sub-Question #4:

How is STEM and strict STEM course availability related to STEM and strict STEM course enrollment during high school?

Results showed that while statistically significant, the difference in STEM enrollment between schools that offered low and high amounts of STEM courses was approximately one STEM course. In other words, STEM course enrollment only varied by one course between low and high STEM available schools, with students in high available STEM schools taking an approximate average of one more STEM course than students in low STEM available schools. This difference was even less meaningful for strict STEM enrollment and availability. This result generally supports the theme of Darolia, Koedel, Main, Ndashimye, and Yan (2018) who found that STEM course availability was not an adequate predictor of postsecondary outcomes. Despite the national push for increased STEM availability in schools (ACT, 2016; White House, 2017) the present results suggest that higher STEM course availability in PA is not necessarily associated with meaningful increases in STEM course enrollment.

To examine this relationship more thoroughly, two ANOVAs tested the effects of total STEM enrollment on LEA STEM availability ranks. Results suggested that increases in STEM enrollment were related to increases in STEM availability. For instance, students who were enrolled in seven or eight STEM courses had an average of around five more STEM courses available to them than students who enrolled in five or six STEM courses. This significant difference in course availability was observed for strict STEM as well. One potential interpretation of this finding is that STEM enrollment has the potential to drive STEM course availability; if students express higher levels of interest in STEM courses as evidenced by enrollment, schools may increase availability to accommodate demand. Future research can dig deeper to determine if student interest in STEM may be related to STEM course offerings in high school.

Sub-Question #5:
Are minority groups, women, and historically underperforming students underrepresented in STEM opportunities in PA?

Results revealed that certain demographic groups, especially some racial and ethnic minority groups and historically underperforming students, are significantly underrepresented in various STEM opportunities in PA. However, differences in representation vary across all outcomes, so each will be discussed in turn.

High School Advanced STEM Course Enrollment

There was a significant difference in the proportion of males and females who enrolled in one or more rigorous strict STEM/STEM courses compared to those who enrolled in none. Females generally enrolled in one or more rigorous STEM courses more often than males did. However, this difference was halved for rigorous strict STEM courses, suggesting that males may lessen this enrollment gap by taking strict rigorous STEM courses. This general finding supports the ideas of Kahn and Ginther (2018) who reported that girls take more AP STEM courses related to the health sciences while boys enroll in AP STEM courses related to mathematics and science.

Results also showed differences between ethnic/racial groups and high school STEM course-taking patterns, especially among rigorous and advanced STEM courses. Around 16% of Black or African American and Hispanic students enrolled in one or more rigorous STEM courses, compared to almost 37% of White students. Generally, there was an approximate 3-6% decrease for all demographic groups for enrollment in one or more rigorous strict STEM courses. These findings coincide with results reported by the U.S. Department of Education (2016) who found that various URM groups participate in STEM courses at a reduced rate compared to their White counterparts.

Lastly, historically underperforming (special education, EL, and economically disadvantaged) students were compared to non-historically underperforming students in terms of high school STEM course enrollment. Results showed that only 17% of historically underperforming students enrolled in a rigorous STEM course, compared to 45% of non-historically underperforming students. Taken together, these findings suggest disparities for various racial/ethnic groups and historically underperforming students in advanced STEM enrollment, but suggest only a moderate difference between males and females (mitigated further by enrollment in rigorous strict STEM courses).

Access to STEM Courses

Findings also suggested differences in STEM access between demographic groups. STEM availability was broken down into three categories: LEAs with low available strict STEM/STEM, LEAs with medium available strict STEM/STEM, and LEAs with high available strict STEM/STEM. Results did not show any significant differences between males and females for STEM or strict STEM availability. However, there was a significant difference between proportions by race/ethnicity. Specifically, over half of Black or African American students were enrolled at schools with low STEM availability (56%) and strict STEM availability (57.7%). Differences between proportions for other racial/ethnic groups were fairly static and not meaningfully different.

For historically underperforming students, differences in STEM availability were similar; 44% of historically underperforming students were located at low STEM available schools compared to 27% of non-historically underperforming students. Results are similar for strict STEM availability, showing a slightly larger disparity. The current results suggest a wide disparity for Black or African American and historically underperforming students in terms of STEM course availability. While previous results indicated that higher availability is not necessarily associated with higher enrollment, a lack of exposure to STEM topics may harm URM groups' opportunities for later STEM success.

Graduation from College with a STEM Degree

Depending on how college graduation with a STEM major was measured, outcomes were different for males and females. Among all female college graduates, only 18% earned a STEM degree but 45% of all STEM Bachelor's degrees went to females. Thirty-five percent of male college graduates earned STEM degrees, and 55% of STEM Bachelor's degree earners were male. This finding indicates that for the cohorts studied, females were generally well-represented among STEM college graduates, but also suggests that most females chose to study degree topics other than STEM. If the present study had access to data regarding college major upon entry, this finding might be further explained. Also, this effect could be influenced by the finding that more females graduated college than males; of all graduates, 60% were female and 40% were male. While previous research (NCES, 2019) and the current study have both found that males earn most STEM degrees, the present findings suggest that women in PA may be closing the gap in earned STEM college degrees.

There were also differences between various racial and ethnic groups for college graduation with a STEM degree. When examining all college graduates, it was found that Black or African American students had the lowest STEM graduation rates, followed by Hispanic students. Asian students graduated with STEM degrees at the highest rate of all demographic groups at over 40%. These results reflect national trends in the literature (NSF, 2014). Among STEM graduates, it was found that White students were substantially overrepresented, indicating a serious disparity for all URM ethnic and racial groups.

Lastly, it was found that a disparity exists in STEM degree completion for historically underperforming students. Only 14.5% of historically underperforming graduates earned a STEM degree, compared to 20.8% of non-historically underperforming students. For strict STEM degrees, the difference grows larger by a small degree; only 13.3% of historically underperforming graduates earned a strict STEM degree, compared to 20.6% of non-historically underperforming students. Together, these results imply that special education, EL, and economically disadvantaged students graduate college with STEM degrees at lower rates than their counterparts without these indicators.

Suggestions for Future Research

One of the major objectives of the present study was to provide direction for future STEM researchers in a variety of areas, including STEM availability, enrollment, postsecondary outcomes, and equity. While the present study investigated the effects of teacher qualifications and STEM employment presence on STEM availability at the county level, future researchers should examine these effects at a more micro or community level. Specifically, researchers should examine STEM workforce estimates at a city or regional level, including teacher information from each LEA aggregated to that level as well. Not only would this provide a higher sample size and therefore increase generalizability, but STEM employment presence may have a more observable association with course availability at the local level.

Also, future research should continue to examine and document potential disparities in STEM representation among URM groups and women. In addition, future studies should make use of census and other readily available data, including student to teacher ratios, parent highest degree, and local tax information. These community focused variables may highlight STEM equity differences in certain communities, allowing for focused interventions aimed at increasing STEM access and enrollment for URM groups.

Limitations

The present study also had several methodological limitations. First, the researchers did not have access to course performance data, so course enrollment information was used to establish links to postsecondary outcomes. Second, National Student Clearinghouse data describing college outcomes did not report students' major choice at college enrollment; instead, researchers only had access to students' final major upon graduation. Access to this data would have allowed for more robust logistic regression modeling and would have painted a more complete picture of the current study's main findings. However, the present study's focus on enrollment highlights the strength of the current findings. Higher rates of high school enrollment in STEM, regardless of course performance, was consistently associated with positive postsecondary outcomes.

To perform linear regression analysis and answer main research question #2, teacher qualifications and STEM course availability needed to be aggregated to the county level to match the format of the STEM workforce occupational data. This may have masked community level effects of teacher qualifications and STEM employer presence on STEM availability. Further, available STEM courses were calculated using the total number of unique STEM course identifiers offered by each LEA during a particular year, in which at least one student was enrolled. Therefore, utilized data shows that all students at an LEA have the same available STEM courses for a given year, regardless of their current grade level. This is problematic considering the average freshman cannot access a rigorous course in physics without completing certain pre-requisites. Although the researchers averaged availability across years before creating low, medium, and high ranks to mitigate this issue, the year-by-year STEM availability measure could have been more accurate if course data were assigned designated grade levels associated with each course.

Lastly, STEM courses, college majors, and occupations were labelled as such in the present study based on various definitions of STEM (U.S. Department of Commerce, 2011; U.S. Department of Homeland Security, 2016). Available data did not allow for STEM to be viewed as an integrative discipline which purposefully incorporates many STEM subject-areas during instruction, giving students a unified, cross-boundary STEM curriculum (Sanders, 2012). As the STEM research field moves closer to viewing STEM as an integrated discipline, more research will be needed which focuses less on individual STEM subject areas and more on unified STEM educational experiences.

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 junctures of the STEM pipeline. The current research suggests that STEM enrollment opportunities in PA high schools can have far-reaching positive effects on students' postsecondary outcomes. Additionally, while focusing on increasing STEM course availability may not necessarily result in increased 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 URM groups in STEM opportunities serves to strengthen the local and nation-wide STEM economy. While STEM engagement for all groups is essential, the current study suggests that the simple act of enrolling in STEM and advanced STEM courses during high school may have a positive, meaningful, and long-lasting influence on the education of Pennsylvania's children.

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Appendix A

List of Operational Definitions

1. A **"Strict" STEM course** refers to any class taken between grades 9 and 12 which is included in any of the following subject area codes, as designated by the School Code for the Exchange of Data (SCED): Mathematics (02), Life and Physical Sciences (03), Information Technology (10) or Engineering and Technology (21).
2. A **"Lenient" STEM course** refers to specific classes taken between grades 9 and 12 which fall under various SCED subject area codes, including Social Sciences and History (04: Economics and Social Sciences sub-categories), Health Care Sciences (14: Health Sciences sub-category), and any course under Category 17: Architecture and Construction.
3. A **STEM course** refers to any class taken between grades 9 and 12 which meets either of the listed requirements above for a "Strict" STEM course or a "Lenient" STEM course (#1 or #2).
4. A **Rigorous course** refers to any course defined as such by the Pennsylvania Department of Education (PDE). This includes any course that meets the Pennsylvania reporting standards for Advanced Placement (AP), Dual Credit, or International Baccalaureate (IB). Additionally, a CTE student who has completed 50% or more of their CTE program is included in PDE's definition of rigorous course-taking students.
5. **A Rigorous "Strict" STEM course** refers to any course that meets the requirements for a strict STEM course and meets the requirements for a rigorous course (#1 and #4).
6. A **Rigorous STEM course** refers to any class that meets the requirements for a STEM course and a rigorous course (#3 and #4).
7. An **Advanced course** refers to any class that meets the listed requirements for a rigorous course or is designated by a PA Local Educational Agency (LEA) as honors or gifted. Because PA LEAs are not required to report honors or gifted courses, totals of such across geographical regions would be incomplete. However, honors and gifted courses that are reported, in addition to rigorous courses, paint a more complete picture of advanced course-taking in PA.
8. An **Advanced STEM course** refers to any class that meets the requirements for a STEM course and for an advanced course (#3 and #7).
9. **Rigorous STEM Availability** refers to the percentage of unique courses offered by each PA county that meets the definitions for a rigorous course and a STEM course. These percentages were calculated by totaling the number of unique courses and unique rigorous STEM courses offered by each LEA by year, aggregating these totals to the county level (for main research question #2), and dividing total available rigorous STEM courses by total available courses to obtain the percentage of rigorous STEM availability.
10. **Advanced STEM Availability** refers to the percentage of unique courses offered by each PA county that meets the requirements for advanced course and STEM course. This percentage was calculated using similar steps as were described in #9.

11. A **“Strict” STEM major** refers to a postsecondary program of study that is defined as STEM by the Department of Homeland Security. Strict STEM degrees are those which contain any of the following CIP code prefixes: Engineering (CIP Code 14), Biological and Biomedical Sciences (CIP Code 26), Mathematics and Statistics (CIP Code 27), and Physical Sciences (CIP Code 40).
12. A **“Lenient” STEM major** refers to a program of postsecondary study that is defined by the Department of Homeland Security as a “related field” to STEM. These include certain majors in the social sciences (CIP Codes 42 and 45), health sciences (CIP Code 51), and others.
13. A **STEM major** refers to any program of postsecondary study that meets the requirements for a “Strict” STEM major or a “Lenient” STEM major (#11 or #12).
14. A **“Strict” STEM occupation** refers to a variety of jobs and professions defined as STEM by the U.S. Department of Commerce (https://files.eric.ed.gov/fulltext/ED522129.pdf). These occupations include jobs heavily involved in mathematics, computer technology, architecture and engineering, and physical and life sciences.
15. A **“Lenient” STEM occupation** refers to any job or profession listed by the U.S. Bureau of Labor and Statistics as STEM which is not included in the U.S. Department of Commerce’s STEM occupations definition. These jobs include occupations in the social sciences, architecture, health care, and other related fields.
16. A **STEM occupation** refers to any job or profession which meets the requirements for a Strict STEM occupation or meets the requirements for a Lenient STEM occupation (#14 or #15).
17. An **Economically Disadvantaged Student** is grouped based on their inclusion in one or more of the following categories: Temporary Assistance for Needy Families cases, census poor, Medicaid, children living in institutions for the neglected or delinquent, supported by foster homes, or free and reduced lunch availability.
18. A **Historically Underperforming Student** is grouped based on their inclusion in one or more of the following categories: special education, English Learner (EL), or economically disadvantaged.

Appendix B

COHORT POPULATION DEMOGRAPHICS FOR ALL STUDENTS (BEFORE FILE REDUCTION)

	9th Grade Cohorts		
	Cohort 1 (2010-2011)	Cohort 2 (2011-2012)	Cohort 3 (2012-2013)
	%(n)	%(n)	%(n)
Overall			
Total	140299	139071	138971
Gender			
Male	51.4 (72115)	50.8 (70672)	51.3 (71225)
Female	48.6 (68184)	49.2 (68399)	48.7 (67746)
Ethnicity			
American Indian/Alaskan Native	0.1 (202)	0.1 (191)	0.2 (212)
Black or African American	15.1 (21147)	15.4 (21379)	15.2 (21190)
Hispanic	8.2 (11501)	8.8 (12171)	9.2 (12836)
White	72.0 (100986)	70.7 (98310)	70.0 (97278)
Multi-Racial	1.3 (1825)	1.5 (2150)	1.8 (2496)
Asian	3.2 (4543)	3.4 (4765)	3.5 (4868)
Native Hawaiian or other Pacific Islander	0.1 (95)	0.1 (105)	0.1 (91)
Historically Underperforming Group			
Yes	44.8 (62833)	46.4 (64558)	46.6 (65015)
No	55.2 (77466)	53.6 (74513)	53.2 (73956)
EL Status			
Yes	2.1 (3003)	2.2 (3071)	2.4 (3308)
No	97.9 (137296)	97.8 (136000)	97.6 (135663)
Special Education Status			
Yes	14.3 (20059)	15.0 (20871)	15.4 (21356)
No	85.7 (120240)	85.0 (118200)	84.6 (117615)
Economically Disadvantaged			
Yes	37.7 (52836)	39.3 (54696)	39.6 (55052)
No	62.3 (87463)	60.7 (84375)	60.4 (83919)

Appendix C

COHORT POPULATION DEMOGRAPHICS FOR STUDENTS WITH ALL YEARS COURSE DATA (BEFORE FILE REDUCTION)

	9th Grade Cohorts			
	Cohort 1 (2010-2011)	Cohort 2 (2011-2012)	Cohort 3 (2012-2013)	Overall
	%(n)	%(n)	%(n)	%(n)
Overall				
Total	115068	113170	112520	340758
Gender				
Male	50.7 (58354)	50.2 (56822)	50.8 (57171)	50.6 (172347)
Female	49.3 (56714)	49.8 (56348)	49.2 (55349)	49.4 (168411)
Ethnicity				
American Indian/Alaskan Native	0.1 (146)	0.1 (131)	0.1 (133)	0.1 (410)
Black or African American	12.4 (14268)	12.3 (13919)	12.1 (13564)	12.3 (41751)
Hispanic	6.5 (7469)	7.1 (8035)	7.3 (8239)	7.0 (23743)
White	76.6 (88172)	75.8 (85770)	75.4 (84819)	75.9 (258761)
Multi-Racial	1.1 (1319)	1.4 (1537)	1.6 (1817)	1.4 (4673)
Asian	3.2 (3629)	3.3 (3701)	3.5 (3886)	3.3 (11218)
Native Hawaiian or other Pacific Islander	0.1 (65)	0.1 (75)	0.1 (62)	0.1 (202)
Historically Underperforming Group				
Yes	40.3 (46382)	41.6 (47073)	41.8 (47067)	41.2 (140522)
No	59.7 (68686)	58.4 (66097)	58.2 (65453)	58.8 (200236)
EL Status				
Yes	1.1 (1232)	1.1 (1235)	1.1 (1290)	1.1 (3757)
No	98.9 (113836)	98.9 (111935)	98.9 (111230)	98.9 (337001)
Special Education Status				
Yes	12.7 (14585)	13.3 (15041)	13.5 (15191)	13.2 (44817)
No	87.3 (100483)	86.7 (98129)	86.5 (97329)	86.8 (295941)
Economically Disadvantaged				
Yes	33.9 (39058)	35.3 (39911)	35.6 (40081)	34.9 (119050)
No	66.1 (76010)	64.7 (73259)	64.4 (72439)	65.1 (221708)

Appendix D

PARTICIPATION IN RIGOROUS STEM COURSES BY COHORT

	Cohort 1 (2010-2011)		Cohort 2 (2011-2012)		Cohort 3 (2012-2013)	
	1 or more	No Classes	1 or more	No Classes	1 or more	No Classes
	%(n)	%(n)	%(n)	%(n)	%(n)	%(n)
Overall						
Total	35(39347)	65(73173)	34.1(38625)	65.9(74545)	31.9(36708)	68.1(78360)
Gender						
Male	31.9(18256)	68.1(38915)	31.1(17690)	68.9(39132)	29.4(17169)	70.6(41185)
Female	38.1(21091)	61.9(34258)	37.2(20935)	62.8(35413)	34.5(19539)	65.5(37175)
Ethnicity						
American Indian/ Alaskan Native	28.6(38)	71.4(95)	32.8(43)	67.2(88)	32.2(47)	67.8(99)
Black or African American	17.3(2341)	82.7(11223)	16.3(2264)	83.7(11655)	15.3(2186)	84.7(12082)
Hispanic	16.4(1355)	83.6(6884)	16.2(1300)	83.8(6735)	16.1(1201)	83.9(6268)
White	38.3(32485)	61.7(52334)	37.5(32144)	62.5(53626)	34.7(30632)	65.3(57540)
Multi-Racial	28.8(523)	71.2(1294)	27.3(420)	72.7(1117)	25.2(333)	74.8(986)
Asian	66.4(2579)	33.6(1307)	65.3(2418)	34.7(1285)	62.9(2283)	37.1(1346)
Native Hawaiian or other Pacific Islander	41.9(26)	58.1(36)	48(36)	52(39)	40(26)	60(39)
Historically Underperforming Group						
Yes	17.9(8402)	82.1(38665)	17.3(8147)	82.7(38926)	16.3(7548)	83.7(38834)
No	47.3(30945)	52.7(34508)	46.1(30478)	53.9(35619)	42.5(29160)	57.5(39526)
EL Status						
Yes	4.9(63)	95.1(1227)	4.8(59)	95.2(1176)	6.3(78)	93.7(1154)
No	35.3(39284)	64.7(71946)	34.5(38566)	65.5(73369)	32.2(36630)	67.8(77206)
Special Education Status						
Yes	6.3(953)	93.7(14238)	6.9(1041)	93.1(14000)	7.2(1046)	92.8(13539)
No	39.4(38394)	60.6(58935)	38.3(37584)	61.7(60545)	35.5(35662)	64.5(64821)
Economically Disadvantaged						
Yes	19.4(7792)	80.6(32289)	18.7(7464)	81.3(32447)	17.5(6828)	82.5(32230)
No	43.6(31555)	56.4(40884)	42.5(31161)	57.5(42098)	39.3(29880)	60.7(46130)

Appendix E

PARTICIPATION IN RIGOROUS STRICT STEM COURSES BY COHORT

	Cohort 1 (2010-2011)		Cohort 2 (2011-2012)		Cohort 3 (2012-2013)	
	1 or more	No Classes	1 or more	No Classes	1 or more	No Classes
	%(n)	%(n)	%(n)	%(n)	%(n)	%(n)
Overall						
Total	30.6(34480)	69.4(78040)	29.6(33490)	70.4(79680)	27.4(31503)	72.6(83565)
Gender						
Male	28.9(16530)	71.1(40641)	27.8(15810)	72.2(41012)	25.9(15140)	74.1(43214)
Female	32.4(17950)	67.6(37399)	31.4(17680)	68.6(38668)	28.9(16363)	71.1(40351)
Ethnicity						
American Indian/ Alaskan Native	24.8(33)	75.2(100)	29(38)	71(93)	26.7(39)	73.3(107)
Black or African American	14.8(2006)	85.2(11558)	13.5(1873)	86.5(12046)	12.8(1828)	87.2(12440)
Hispanic	13.9(1148)	86.1(7091)	13.7(1099)	86.3(6936)	13.6(1019)	86.4(6450)
White	33.5(28449)	66.5(56370)	32.5(27854)	67.5(57916)	29.8(26238)	70.2(61934)
Multi-Racial	24.4(444)	75.6(1373)	23.4(360)	76.6(1177)	21.2(279)	78.8(1040)
Asian	61.1(2375)	38.9(1511)	60.2(2231)	39.8(1472)	57.2(2077)	42.8(1552)
Native Hawaiian or other Pacific Islander	40.3(25)	59.7(37)	46.7(35)	53.3(40)	35.4(23)	64.6(42)
Historically Underperforming Group						
Yes	15.6(7335)	84.4(39732)	15(7072)	85(40001)	13.9(6450)	86.1(39932)
No	41.5(27145)	58.5(38308)	40(26418)	60(39679)	36.5(25053)	63.5(43633)
EL Status						
Yes	4.3(56)	95.7(1234)	4.4(54)	95.6(1181)	5.4(67)	94.6(1165)
No	30.9(34424)	69.1(76806)	29.9(33436)	70.1(78499)	27.6(31436)	72.4(82400)
Special Education Status						
Yes	5.2(787)	94.8(14404)	5.7(853)	94.3(14188)	5.8(845)	94.2(13740)
No	34.6(33693)	65.4(63636)	33.3(32637)	66.7(65492)	30.5(30658)	69.5(69825)
Economically Disadvantaged						
Yes	17.1(6838)	82.9(33243)	16.3(6515)	83.7(33396)	15(5867)	85(33191)
No	38.2(27642)	61.8(44797)	36.8(26975)	63.2(46284)	33.7(25636)	66.3(50374)

Appendix F

PARTICIPATION IN ADVANCED STEM COURSES BY COHORT

	Cohort 1 (2010-2011)		Cohort 2 (2011-2012)		Cohort 3 (2012-2013)	
	1 or more	No Classes	1 or more	No Classes	1 or more	No Classes
	%(n)	%(n)	%(n)	%(n)	%(n)	%(n)
Overall						
Total	53(59604)	47(52916)	52.9(59869)	47.1(53301)	51.3(59020)	48.7(56048)
Gender						
Male	48.9(27944)	51.1(29227)	49(27855)	51(28967)	47.9(27970)	52.1(30384)
Female	57.2(31660)	42.8(23689)	56.8(32014)	43.2(24334)	54.7(31050)	45.3(25664)
Ethnicity						
American Indian/ Alaskan Native	45.1(60)	54.9(73)	48.1(63)	51.9(68)	52.1(76)	47.9(70)
Black or African American	38(5148)	62(8416)	38(5288)	62(8631)	38(5419)	62(8849)
Hispanic	38.8(3193)	61.2(5046)	37.6(3020)	62.4(5015)	38.1(2844)	61.9(4625)
White	55.7(47220)	44.3(37599)	55.7(47749)	44.3(38021)	53.6(47260)	46.4(40912)
Multi-Racial	46.8(850)	53.2(967)	48.2(741)	51.8(796)	46.3(611)	53.7(708)
Asian	79.7(3097)	20.3(789)	79.9(2959)	20.1(744)	76.5(2775)	23.5(854)
Native Hawaiian or other Pacific Islander	58.1(36)	41.9(26)	65.3(49)	34.7(26)	53.8(35)	46.2(30)
Historically Underperforming Group						
Yes	34.7(16345)	65.3(30722)	34.9(16430)	65.1(30643)	34.3(15924)	65.7(30458)
No	66.1(43259)	33.9(22194)	65.7(43439)	34.3(22658)	62.7(43096)	37.3(25590)
EL Status						
Yes	16.2(209)	83.8(1081)	15.6(193)	84.4(1042)	15.7(193)	84.3(1039)
No	53.4(59395)	46.6(51835)	53.3(59676)	46.7(52259)	51.7(58827)	48.3(55009)
Special Education Status						
Yes	14.1(2141)	85.9(13050)	15.1(2277)	84.9(12764)	15.1(2196)	84.9(12389)
No	59(57463)	41(39866)	58.7(57592)	41.3(40537)	56.6(56824)	43.4(43659)
Economically Disadvantaged						
Yes	37.7(15113)	62.3(24968)	37.9(15111)	62.1(24800)	37.2(14547)	62.8(24511)
No	61.4(44491)	38.6(27948)	61.1(44758)	38.9(28501)	58.5(44473)	41.5(31537)

Appendix G

Study Overview: Objectives, Research Questions, Analytic Steps and Sample

Major Objectives	PDE Research Questions	Analytic sample (Population)*	Analytic Steps	Additional Sub-questions
Identify the science, technology, engineering, and math (STEM) course-taking patterns among high school students in Pennsylvania.	Are STEM course-taking patterns in high school associated with postsecondary trajectory, as defined by college enrollment, persistence and retention through college, and college graduation?	Three cohorts of 9th grade students from school years 2010/2011, 2011/2012, 2012/2013 for high school graduation, post-secondary enrollment, major choice, and persistence through Year 2; One cohort for on-time completion.	1. Descriptive analyses to examine variable distributions, frequencies, means, and standard deviations.	**Phase 1** What is the description and breakdown of student cohort populations by year and grade?
Connect STEM course-taking patterns to students' postsecondary trajectories, including college enrollment, major choice (physics, chemistry, computer science, etc.), persistence, and graduation.	Are teacher qualifications/ credentials (years of teaching experience and highest degree) and the presence of STEM employment in PA counties associated with the availability of high-quality STEM education in PA schools?		2. Description of students on key variables of interest.	Are postsecondary trajectories differentially affected by advanced STEM courses taken early in high school as opposed to later in high school?
Investigate the availability of STEM education in various school districts and determine if teacher qualifications and regional STEM employer presence influence high-quality STEM availability (honors, Advanced Placement STEM courses, etc.).			3. Exploratory and predictive analyses included comparisons of students across key variables of interest using varied inferential statistical analysis techniques, including the following: Analysis of Variance (ANOVA) Chi-Square and Logistic Regression Analysis.	Are factors related to STEM education and STEM employment availability in a student's county associated with his or her college major upon graduation?
Determine if various minority groups are significantly under-represented in STEM education in PA.				How are STEM and strict STEM course availability related to STEM and strict STEM course enrollment during high school?
Provide direction for future research to guide policy decisions geared toward increasing STEM availability and opportunities for STEM-related employment.				Are minority groups significantly underrepresented in STEM opportunities in PA?

Appendix H

Institutional Review Board (IRB) Approved Variable List

Variable Type	Description	Data Source
Outcome Variables (Dependent Variables)		
High School STEM Availability	• Total number of STEM classes and strict STEM classes offered by each LEA • Number of advanced STEM courses (honors, gifted, AP, IB, Dual-Credit) offered by a county	PIMS
Graduation from High School	• Dichotomous variable: Graduation on time at 4-years versus Not.	PIMS
Postsecondary Enrollment	• Enrollment versus Not Enrolled. • If enrolled, 2-Year versus 4-Year;	PIMS/NSC
Postsecondary Enrollment Status	• Categorical variable: Full-time; Half-time; Three-quarter time; Less than half-time	NSC
Postsecondary Major, STEM/non-STEM	• Categorical variable indicating choice of major; and • Dichotomous variable indicating choice of STEM major or non-STEM major; and • Categorical variable indicating subcategory of chosen STEM major (science, math, health, etc.)	NSC
Postsecondary Retention/Attrition	• First- to second-year. • Second- to third-year.	PIMS/NSC
Postsecondary Persistence/ Graduation	• Returning to college for 2nd year and subsequent years. • Graduation status (Dichotomous variable indicating graduated or did not).	PIMS/NSC

Variable Type	Description	Data Source
Independent Variables		
High School STEM Course Enrollment	• Continuous variable: Total number of strict STEM/STEM, strict rigorous STEM/rigorous STEM, and advanced STEM courses enrolled	PIMS
Course Status as STEM/non-STEM	• Dichotomous variable: STEM/non-STEM class, strict STEM/non-strict STEM class, rigorous STEM/non-rigorous STEM class, rigorous strict STEM/non-rigorous strict STEM, advanced STEM/non-advanced STEM	PIMS/SCED
County-wide STEM Employment Presence	• Percentage of jobs in a county which are considered STEM, strict STEM, and lenient STEM occupations	DLI Occupational Workforce Data
Staff Years Experience	• Continuous measure of total years of teaching experience possessed by instructors.	PIMS
Staff Years Experience in District	• Continuous measure of total years of teaching experience instructors have working at their primary LEA.	
Staff Highest Degree	• Categorical variable: indicates the highest level of education possessed by instructors.	PIMS

Appendix H

Institutional Review Board (IRB) Approved Variable List

Variable Type	Description	Data Source
Covariates		
Student Gender	• Dichotomous measure of male versus female.	PIMS
Student Ethnicity	• Categorical variable that includes the following: American Indian/Alaskan Native, Black or African American, Hispanic, White, Multi-racial, Asian, Native Hawaiian or Pacific Islander.	PIMS
Student Socioeconomic Status	• Dichotomous variable: Economic Disadvantaged Status code (Y/N)	PIMS
Staff Gender	• Dichotomous measure of male versus female.	PIMS
Staff Ethnicity	• Categorical variable that includes the following: American Indian/Alaskan Native, Black or African American, Hispanic, White, Multi-Racial, Asian, Native Hawaiian or other Pacific Islander.	
Student EL Status	• Dichotomous variable: EL status, non-EL status	PIMS
Student Special Education Status	• Dichotomous variable: Special education status/ non-special education status	PIMS

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POL PK-20 Policy

ECE Early Childhood Education

K12 K-12 Education

PSE Postsecondary Education

WRK Workforce

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The mission of the Department of Education is to ensure that every learner has access to a world-class education system that academically prepares children and adults to succeed as productive citizens. Further, the Department seeks to establish a culture that is committed to improving opportunities throughout the commonwealth by ensuring that technical support, resources, and optimal learning environments are available for all students, whether children or adults.