STEM ASSESSMENT REPORT: PHASE I

COMMISSIONED AND DEVELOPED BY BIOTN

STEM-related work is the fastest-growing economic sector in the United States. And when Tennessee's students are provided with opportunity and investment, they outperform their peers. This is the good news from BioTN's new and comprehensive STEM Assessment Report. The challenge is that Tennessee still ranks in the middle of the pack in STEM educational achievement, indicating that there is a lot more work to be done for our students to excel.

We are pleased to present Phase 1 of this report, which analyzes the state of science-, technology-, engineering- and math-based professions in Tennessee, and our education system's preparedness to meet the increase in demand for STEM-focused workers to fill these high-wage positions.

STEM-related jobs currently account for about 23 percent of the U.S. workforce. Careers in STEM are the primary drivers of economic advancement in the U.S. and are key to building a better economy for Tennesseans. Ensuring there are enough qualified STEM workers, as well as better participation from under-represented groups, will take a strategic focus on K-12 STEM education and increased access to college preparatory programs that promote STEM careers.

We have good news to report here, but also a cautionary note. When Tennessee invests in STEM programs, our students outperform their peers from other states. But maintaining those advances has proven challenging and requires purposeful and continued focus and investment. Furthermore, while Tennessee students' rank in math and science has improved over the last decade as compared to other students across the country, it is largely a function of the performance of Tennessee students maintaining flat, but steady achievement scores, while the average scores of students in other states have declined.

Tennessee students' math and science performance has improved overall since 2010, fueled by intentional statewide focus in the early 2010s. However, many of those overall gains have been offset by a noticeable dropoff that began in 2015, in conjunction with the adoption of new standards and new testing rubrics, and accelerated during the COVID-19 pandemic.

This report illustrates the urgency and opportunity Tennessee's STEM educators currently face, and the importance of redoubling our efforts as a state to prioritize STEM education.

In Phase 2 of our assessment, targeted for release in 2024, we will explore the lasting impacts of some of the programs and initiatives spotlighted in Phase 1, highlight successful national efforts to improve STEM education, and offer recommendations for how Tennessee can continue to promote STEM education and increase student success.

Sincerely,

Dr. Samuel Lynch
Chairman
BioTN

Abby Trotter
Executive Director
BioTN

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EXECUTIVE SUMMARY

Purpose of this Investigation

In 2016, analyses developed by the state's Department of Labor and Workforce Development found that there were approximately 138,000 Science Technology Engineering and Math (STEM) employees in Tennessee (Tennessee Department of Labor and Workforce Development, 2019). These estimates expect by 2026 that the state's STEM workforce will add nearly 30,000 jobs, and that these new jobs will represent 8.44 percent of the total jobs being added in the state. The same analysis found that STEM occupation growth rates are projected to exceed job growth rates overall. STEM jobs are expected to grow by 21.6 percent from 2016 to 2026, while the growth rate for all jobs is expected to be 11.4 percent.

Demand for STEM workers is not only a future need. Current workforce data also highlights the need for skilled STEM workers (Tennessee Higher Education Commission, 2022). Of the 100 occupations categorized as STEM by the Bureau of Labor Statistics (BLS), 98 have a currently posted job opening in Tennessee, and two-thirds of STEM occupations had a shortage of candidates compared to job listings Tennessee Higher Education Commission, 2022).

Additionally, a number of STEM occupations are considered particularly in-demand (Tennessee Higher Education Commission, 2022). In Tennessee's annual Supply and Demand report, occupations are considered as in-demand when two of three measures of demand (job postings, projected job openings, or hires) are above the median relative to other occupations in a region. Based on 2022 data, Tennessee currently has 29 of 100 STEM occupation groups classified as in-demand across various regions of the state (Tennessee Higher Education Commission, 2022). Of these 29 in-demand STEM occupations, 8 require an associate's degree or some college, 20 require a bachelor's degree, and 1 requires a doctoral or professional degree (Tennessee Higher Education Commission, 2022). Additionally, all 29 of these occupations are connected to one of the state's nine target industries, a list created by the Tennessee Department of Economic and Community Development to align and prioritize economic development opportunities across the state, meaning these jobs are particularly valuable to employers being recruited to Tennessee (Tennessee Higher Education Commission, 2022).

Understanding the rising importance of STEM jobs, Tennessee, like many states, increased its focus on STEM education in the late 2000s and early 2010s through a number of policies, grants, and programs. Most notably, the state's Race to the Top grant, as well as recent efforts to align K-12 and postsecondary with workforce needs, has resulted in a number of STEM-related programs and initiatives. Most schools in the state now offer and have access to STEM curriculum, and 114 schools have received a STEM designation by the Tennessee STEM Innovation Network (TSIN) (TDOE, TSIN Announce 26 Tennessee Schools Receive STEM/STEAM Designation, 2023).

Given this expansion of STEM programming over the last decade, this report and its companion second part, to be released in early 2024, seek to provide a comprehensive progress report of Tennessee's STEM performance since 2011.

Methodology

STEM education serves to build interest and skills in subjects that point toward postsecondary pathways in STEM disciplines and ultimately predict entry into STEM careers. Despite limitations in the ability to measure effective STEM pedagogy emphasizing inquiry and productive struggle, research has shown that K-12 achievement scores in math and science are strong predictors of postsecondary STEM enrollment and subsequent STEM careers (Lichtenberger & George-Jackson, 2013; Leyva et al., 2022; Wiebe et al., 2018; Hinojosa, T. et al., 2016). The National Science Board (2022) concluded that "Elementary and secondary education in mathematics and science are the foundation for entry into postsecondary STEM majors and STEM-related occupations."

The state of STEM education in Tennessee, then, may be assessed using available math and science achievement data first. This report draws on Tennessee's annual achievement assessments for students in grades 3-8 and the end of high school course tests in Algebra I and Biology to understand how Tennessee students perform against state standards both at present and over time. To enable inter-state comparisons, we also draw on data from the National Assessment of Educational Progress (NAEP). The NAEP uses samples of students in each state to arrive at its measures. Other data, such as Tennessee student results on the ACT math and science sections also shed light on the state of STEM education in Tennessee, and this data as well as other useful measures form the core of this assessment.

K-12 achievement scores in math and science are strong predictors of postsecondary STEM enrollment and subsequent STEM careers.

About BioTN

Since 2007 BioTN, a 501c(3) organization, has been a leader in life science and STEM-related education, economic and workforce development programs, partnerships and advocacy efforts. BioTN's mission is to promote:

- Knowledge of, and education in, STEM and the biosciences
- Innovation and entrepreneurship in STEM and the biosciences
- The positive impact of STEM and the biosciences on human health

As a result, BioTN is committed to building the next wave of bio-STEM professionals by promoting STEM education across Tennessee. We believe that support for STEM education should be expanded through innovative, goal-oriented, measurable programs, world leading STEM focused schools and leading stakeholder organizations across the state. BioTN's long-term vision is to 1) double the number of Tennessee's middle and high school students interested in pursuing STEM-related post-secondary education; and 2) increase by at least 33% the number of middle and high school students academically prepared to pursue STEM-related post-secondary education.

Key Research Questions and Findings

GROWING DEMANDS FOR A STEM WORKFORCE

What are the needs and current state of the STEM workforce in Tennessee and how does this compare to national trends?

- *Across the United States there are more than 9,880,200 STEM jobs, or 6.2 percent, of the total workforce. Analyses predict that STEM jobs will grow by 10.8 percent across the next decade.*
- *Growth in STEM occupations in Tennessee outpaces that of the national average, with increases of more than 20 percent anticipated.*

How many students are moving into STEM fields? Once we know the workforce needs, is the state preparing enough students to meet the STEM workforce demands?

- *Overall postsecondary degree production has declined in Tennessee in recent years, including the number of those students graduating in STEM fields. However, STEM degree production has seen smaller declines than all degrees.*
- *Workforce needs eclipse the number of STEM workers finishing relevant degrees and moving into the workforce. These gaps are especially true in several particularly in-demand STEM and health sciences occupations.*

ASSESSING PREPARATION FOR CAREERS IN STEM FIELDS AMONG TENNESSEE'S K-12 STUDENTS

How are Tennessee's K-12 students performing in STEM education between 2011 and 2022?

- *Tennessee's students showed improvement in STEM-related academic outcomes from 2009-2015; however, when comparing Tennessee Assessment Data (TCAP/TN Ready) with NAEP sampling data, those gains appear more closely linked with Tennessee's relatively less rigorous standards prior to adoption and assessment of first the Common Core State Standards (CCSS) and then the new Tennessee State Standards adopted in 2015.*
- *With Tennessee's new academic standards in place, some data may show slow, positive gains in student outcomes between 2016 and 2019, but there are too few data points from that brief period to indicate a positive trend.*
- *Almost all assessment data that is comparable between 2019 and 2021/2022 show declining performance associated with the many academic disruptions due to the global COVID-19 pandemic.*
- *More specific metrics are needed.*
- *Aligned and consistent testing plays an important role.*

Key Research Questions and Findings

HOW DOES THE PERFORMANCE OF TENNESSEE K-12 STUDENTS COMPARE WITH OTHER STATES SINCE THE RACE TO THE TOP AWARD?

- *Tennessee students generally improved more rapidly than students in Race to the Top comparison states from 2011-2019 (last pre-COVID data).*
- *During COVID, Tennessee proficiency rates declined less than the rates in Race to the Top Comparison states.*
- *The NAEP Assessment shows proficiency rates in other Race to the Top states declining significantly more than Tennessee's rates both before COVID and even more significantly during COVID. As a result, Tennessee's math outcomes are now statistically similar to the average proficiency rates among national public schools, and the state's relative rankings have improved, even while its proficiency rates have remained flat.*

HOW DOES THE PERFORMANCE OF TENNESSEE K-12 STUDENTS COMPARE WITH OTHER STATES SINCE THE RACE TO THE TOP AWARD?

- *Substantial inequities persist across race and socioeconomic indicators.*
- *Further investigation and understanding of causes of continuing disparities in K12 outcomes across race and income classifications is needed.*
- *Deeper understanding of the role of Algebra as gatekeeper to high school graduation, postsecondary matriculation, persistence, and completion, and associated interests and identities should be centered in any recommendations for reducing disparities.*
- *More investigation of the experiences of females in STEM courses and careers is needed to uncover more explanation of their relatively positive K12 achievement levels in math and science courses as compared to their persistent underrepresentation in STEM career fields.*
- *Disparity data in K12 math, science, technology, and engineering literacy show that ambitious goals like those in Tennessee's Race to the Top Application alone, in the absence of sustained, specific, and culturally responsive interventions have done little to move the results.*

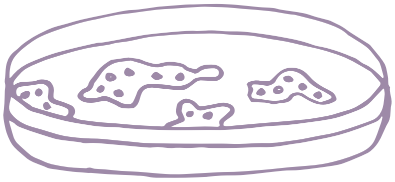
EXAMINING TENNESSEE'S EFFORTS TO IMPROVE STEM PERFORMANCE

What STEM education initiatives were funded through Tennessee's 2010 Race to the Top award and what was their impact?

- *In order to meet the STEM priority its successful Race to the Top application, Tennessee addressed three areas (RMC Research Corporation, 2011, p. 2): Increasing rigor in STEM courses of study; preparing and assisting teachers to integrate STEM across grades and disciplines offering effective and relevant instruction and applied learning opportunities; addressing the needs of under-represented groups and of women and girls in the STEM areas.*
- *Included in Tennessee's Race to the Top application were reforms already underway like the transition to the Tennessee Diploma Project, which brought about more rigorous academic standards in math and science.*
- *Another key initiative launched by the Race to the Top award was the Tennessee STEM Innovation Network (TSIN). This network has gone on to launch partnerships between K12, higher education, and workforce partners across the state as well as begin a STEM school designation program.*

What other initiatives/programs have impacted STEM since the Race to the Top award?

- *In the 13 years since Tennessee was awarded its $500 million Race to the Top grant, the state has also invested in several new efforts to promote and support STEM education. These initiatives span from focusing on additional changes in academic standards and curriculum to improving STEM course access.*
- *Additional focus has been on connection to workforce and industry readiness. Several state initiatives have sought to invest resources and training in improving career and technical education offerings to align with key workforce needs, including STEM occupations.*



INTRODUCTION

While science and math education were among the priorities identified in the 1983 report, A Nation at Risk, grouping them under the label of STEM did not occur until the early 2000's and was not used in an official way until 2005 (Loewus, 2020). Technology, owing to the rapid advance of the microchip, has also received attention, sometimes showing up as shorthand for computer science and other times pointing toward career and technical education programs. Engineering was not mentioned at all in A Nation at Risk, except in reference to institutions or titles of witnesses who participated in the hearings that led to that report. Yet the conclusions from A Nation at Risk were clear. "Educational researcher Paul Hurd concluded at the end of a thorough national survey of student achievement that within the context of the modern scientific revolution, "We are raising a new generation of Americans that is scientifically and technologically illiterate."" In an eerily prescient prediction, "John Slaughter, a former Director of the National Science Foundation, warned of "a growing chasm between a small scientific and technological elite and a citizenry ill-informed, indeed uninformed, on issues with a science component"" (The National Commission on Excellence in Education, 1983).

Many sources first credit Judith A. Ramaley, who was the assistant director for education and human resources at the National Science Foundation from 2001-2004, for introducing the term STEM (science, technology, engineering and math) in the education vernacular (Loewus, 2020). The early 2000s saw the permeation of the term into mainstream education conversations due to the release of several important research reports like 2007's (Institute of Medicine et al., 2007), released by the U.S. National Academies of Science, Engineering, and Medicine. This report emphasized the links between economic success and skilled jobs dependent on science and technology, and noted that U.S. students were not achieving at the same rate as students in other countries in the STEM disciplines (Institute of Medicine et al., 2007). This research helped to elevate the importance of STEM disciplines and promoted STEM's inclusion into President George W. Bush's education funding priorities, further spreading the focus on STEM education throughout K-12 schools.

Most schools in the state now offer and have access to STEM curriculum and 114 schools have received a STEM designation by the Tennessee STEM Innovation Network.

Tennessee, like many states, increased its focus on STEM education in the late 2000s and early 2010s through a number of policies, grants, and programs. Most notably, the state's Race to the Top grant as well as recent efforts to align K-12 and postsecondary with workforce needs has resulted in a number of STEM related programs and initiatives. Most schools in the state now offer and have access to STEM curriculum and 114 schools have received a STEM designation by the Tennessee STEM Innovation Network (TSIN) (*TDOE, TSIN Announce 26 Tennessee Schools Receive STEM/STEAM Designation*, 2023). Given this expansion of STEM programming over the last decade, this report and its companion second part to be released later seek to provide a comprehensive progress report of Tennessee's STEM performance.

For the purposes of this report, we define STEM as not only an integrated approach to teaching science, math, engineering, technology, but we also analyze each of the components as specific disciplines. This is in large part due to the availability of workforce and assessment data which often provide discrete data for individual disciplines like science or math. We intentionally take a broad approach to STEM to craft an overall picture as the varied sources of workforce and K-12 data help to capture a robust STEM assessment. The intent is to capture a broad understanding of the preparation that students receive to equip them for STEM occupations, including but not limited to engineering, lab technicians, and those in the medical profession.

This report is Part I of a two part release. Part I seeks to understand Tennessee STEM outcomes over the last decade and uncover those programs, policies, and initiatives that have impacted those outcomes. In Part II, we will look forward to identifying key needs and promising practices and programs to guide the next phase of STEM education in Tennessee.

GROWING DEMANDS FOR A STEM WORKFORCE

The National Landscape

Nationally, demand for STEM workers is growing. By all measures, high-wage, low-unemployment STEM jobs are among the most widely available and often hard to fill jobs, and growing demand is already built in. We analyzed several reports and analyses on the STEM workforce, and each defines "STEM occupation" a bit differently.

The Bureau of Labor Statistics (BLS) defines STEM occupations as "computer and mathematical, architecture and engineering, and life and physical science occupations, as well as managerial and postsecondary teaching occupations related to these functional areas and sales occupations requiring scientific or technical knowledge at the postsecondary level." This definition classifies 100 different occupation groups as STEM; it does not include occupations in health sciences, occupations that do not require postsecondary knowledge, or K-12 STEM educators. The BLS found that in 2021 employment in STEM occupations totaled 9,880,200 jobs, or 6.2 percent, of the total workforce. Their analyses predict that STEM jobs will grow by 10.8 percent by the year 2031 (Bureau of Labor Statistics, 2022a).

The National Science Foundation (NSF) provides a more expansive view when analyzing the STEM workforce. They include not only those occupations classified by the BLS but they also include science and engineering related occupations, which include those in health, science and engineering management, K-12 science and engineering teachers, and technologists and technicians. Their analysis also includes those occupations without postsecondary requirements. The NSF's recent report, *The State of U.S. Science and Engineering 2022*, finds a workforce of 36 million people, or 23 percent of the total U.S. workforce, is employed in science and engineering or science and engineering-related occupations (Burke et al., 2022).

Another report by the American Association for the Advancement of Science (AAAS) casts an even broader view of the STEM workforce. AAAS uses data from the Bureau of Economic Analysis to examine the STEM workforce. This data set views a STEM "job as a 'task' or 'roster slot' offered by an employer, not an employed worker" like the BLS data (American Association for the Advancement of Science, 2020, p. 10). Under this definition, AAS found that there are more than 64 million STEM jobs in the United States, and 59 percent of those jobs were held by individuals without a bachelor's degree (American Association for the Advancement of Science, 2020).

Each of these analyses demonstrate not only the growing and important nature of the STEM field but also the personal and macroeconomic impact of these jobs. 2021 BLS data finds that wages for STEM occupations are $95,420 are more than double that of non-STEM occupations ($40,120) (Bureau of Labor Statistics, 2022a). Workers in STEM occupations also experience lower unemployment (2 percent) compared with non-STEM occupations at 4 percent unemployment (Burke et al., 2022). Not only do individuals benefit from associated wages and lower unemployment, but the STEM economy also has a tremendous impact on the U.S. economy. In research from the American Association for the Advancement of Science (2020), the STEM workforce is estimated to impact more than 39.3 percent of the US gross domestic product.

Jobs in the biosciences are growing even faster. In 2021, the bioscience industry employed more than 2 million people across every state in the United States (TEConomy Partners, LLC et al., 2022). This number represents significant growth of more than 11 percent since 2018, especially notable given the job declines in other career fields experienced during the COVID-19 pandemic of 2020 and 2021. Bioscience jobs also generate significant impact on the economy and are particularly desirable due to their higher wages. For example, in 2021 biosciences jobs paid an average salary of $126,000 per year compared with the $58,000 per year average of overall private sector jobs (TEConomy Partners, LLC et al., 2022).

Tennessee's STEM Labor Market

With context on the national STEM labor market, we now turn to understand how Tennessee compares and whether the state is experiencing the same growth as the national STEM labor market. Analyses developed by the state's Department of Labor and Workforce Development, utilize BLS data. In 2016, the state found that there were approximately 138,000 STEM employees in Tennessee (Tennessee Department of Labor and Workforce Development, 2019). Estimates expect by 2026 that the state's STEM workforce will add nearly 30,000 jobs, and that these new jobs will represent 8.44 percent of the total jobs being added in the state (Tennessee Department of Labor and Workforce Development, 2019). This same report found that STEM occupations are projected to grow nearly twice as rapidly as all occupations in Tennessee, and new STEM jobs as a whole are expected to grow by 21.6 percent from 2016 to 2026, while growth rate for all jobs is expected to be 11.4 percent.

Demand for STEM workers is not only a future need. Current workforce data also highlights the need for skilled STEM workers (Tennessee Higher Education Commission, 2022). Of the 100 occupations categorized as STEM by the Bureau of Labor Statistics (BLS), 98 have a currently posted job opening in Tennessee, and two-thirds of STEM occupations had a shortage of candidates compared to job listings (Tennessee Higher Education Commission, 2022).

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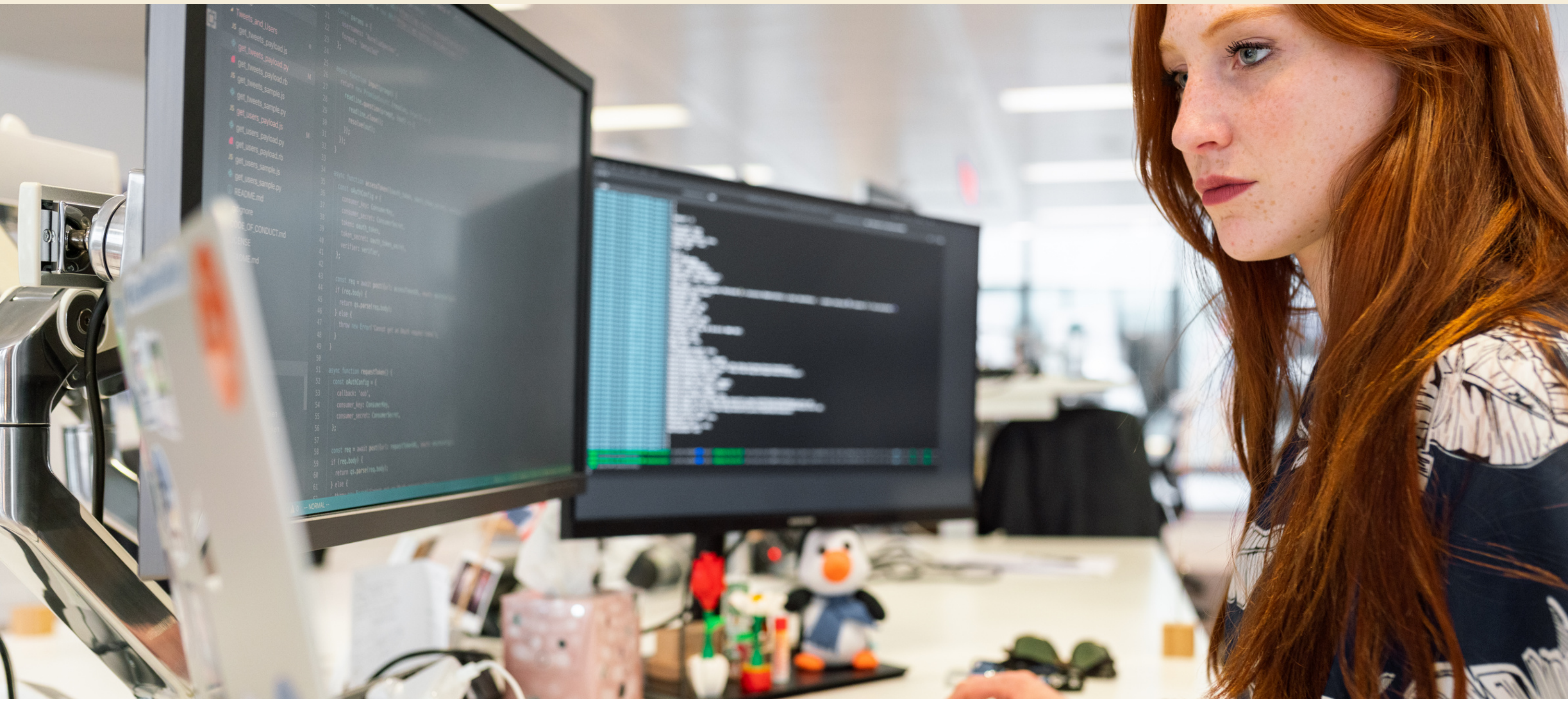
Additionally, all 29 of these occupations are connected to one of the state's nine target industries, a list created by the Tennessee Department of Economic and Community Development to align and prioritize economic development opportunities across the state, meaning these jobs are particularly valuable to employers being recruited to Tennessee (Tennessee Higher Education Commission, 2022).

IN-DEMAND OCCUPATION SPOTLIGHT:

Civil Engineering

- In 2019, there were 0.18 candidates for every civil engineering job opening in the state.
- Projected annual openings (2018-2028) 352, with 1,110 openings advertised online in 2020.
- In 2020, there were 222 completers with Bachelor's degrees, 46 with Master's degrees, and 16 with Doctoral degrees in civil engineering (284 total).
- In 2019, there were 94 high school students statewide completing an engineering related CTE concentration

Tennessee Higher Education Commission, 2022



Eight of the 29 in-demand STEM occupations in Tennessee are in-demand across the entire state (Tennessee Higher Education Commission, 2022). These occupations are clustered in the computer and mathematical, architecture and engineering, and life, physical, and social science occupational groups. Figure 1 outlines the specific occupations considered in-demand statewide.

Figure 1: Tennessee's Statewide In-demand Occupations

Computer and Mathematical Occupational Group	Architecture and Engineering Occupational Group	Life, Physical, and Social Science Occupational Group
Information Security Analysts	Civil Engineers	Environmental Scientists and Specialists, Including Health
Computer Programmers	Electrical and Electronic Engineering Technologists and Technicians	
Software Developers and Software Quality Assurance Analysts and Testers	Calibration Technologists and Technicians and Engineering Technologists and Technicians, Except Drafters	
Operations Research Analysts		

Source: TN Department of Labor and Workforce Development

Additional data analyses examine Tennessee's biosciences job market. Tennessee's biosciences sector has grown by more than 7 percent since 2018 (TEConomy Partners, LLC & BIO Biotechnology Innovation Organization, 2022). With this growth, the number of Tennesseans employed in the biosciences field surpassed 44,000 in 2021 (TEConomy Partners, LLC & BIO Biotechnology Innovation Organization, 2022). Bioscience fields that are particularly strong in Tennessee include bioscience-related distribution and medical device manufacturing (TEConomy Partners, LLC & BIO Biotechnology Innovation Organization, 2022).

IN-DEMAND OCCUPATION SPOTLIGHT:

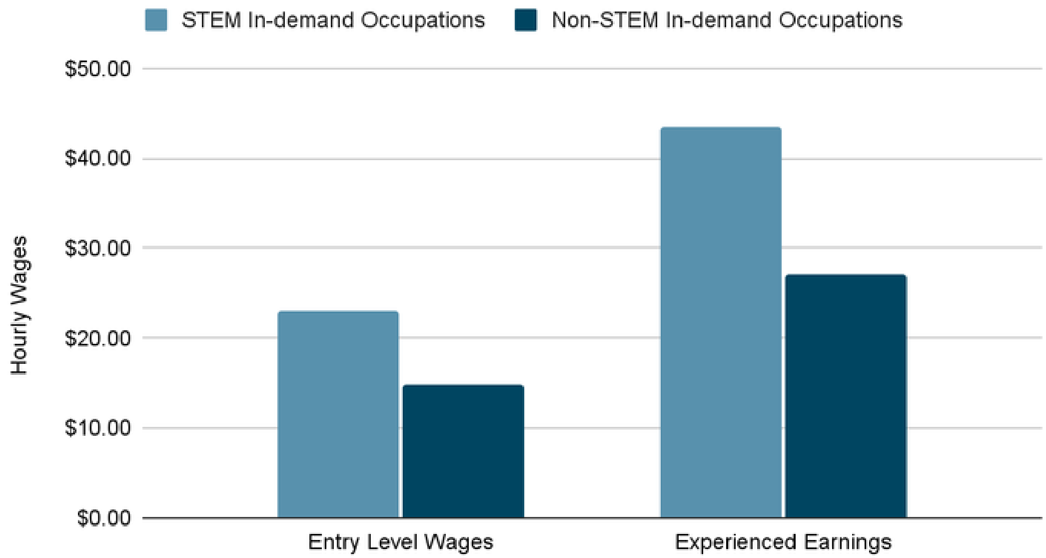
Electrical and Electronic Engineering Technologists and Technicians

- Projected annual openings (2018-2028) 342, 946 job postings advertised online in 2020
- 2020 Completers: Certificate program 75, Associates degree 118, 11 apprenticeship completers in 2020, 204 total
- 2019 CTE completers in related fields: 8 (electromechanical and instrumentation and maintenance technology) and 1 in industrial mechanics and maintenance technology

Tennessee Higher Education Commission, 2022

As with the national data, STEM jobs in Tennessee also pay more on average than non-STEM jobs. The state's Department of Labor and Workforce Development (2019) finds that "the median salary of Tennesseans employed in STEM occupations, $70,849, is more than twice the median salary for all occupations ($34,895)." The higher rates of STEM salaries also continue when compared to other in-demand occupations. Figure 2 highlights the differences in STEM earnings vs. non-STEM earnings for in-demand occupations and shows how the gap widens with experience (Tennessee Higher Education Commission, 2022).

Figure 2: STEM In-Demand vs. Non-STEM In-Demand Wages



Source: TN Department of Labor and Workforce Development

Tennessee's Health Sciences Labor Market

Neither national data from the Bureau of Labor Statistics nor state data from the Tennessee Department of Labor and Workforce classifies health sciences occupations as "STEM occupations;" however, BioTN believes that these occupations draw upon STEM skills and knowledge and are essential to understanding the full landscape of the STEM job market and needs in Tennessee. Similar to the rate of growth of STEM jobs, national data projects that overall employment in healthcare occupations will grow more than 13 percent from 2021 to 2031 (Bureau of Labor Statistics, 2022b).

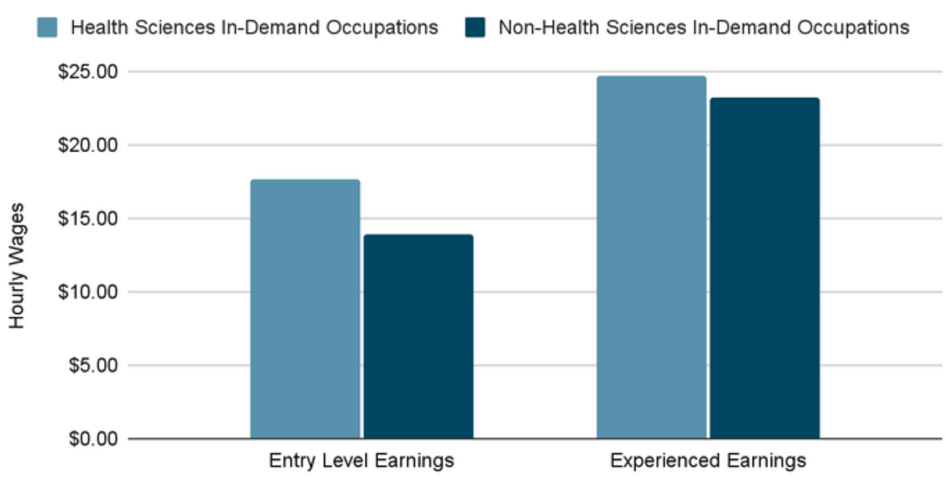
Tennessee's demand for jobs in healthcare is also growing rapidly. Figure 3 illustrates the health sciences occupations that are considered in high-demand across Tennessee along with the number of 2020 jobs in each occupation and projections for the number of jobs in 2028 (Tennessee Higher Education Commission, 2022).

Figure 3: Health Sciences Occupational Projections

Occupation (Number of Regions in Demand)*	2020 Jobs	2028 Projected Employment
Clinical, Counseling, and School Psychologists (5)	1,290	3,046
Physician Assistants (5)	2,080	3,040
Surgical Technologists (6)	2,250	3,513
Physical Therapist Assistants (10)	3,060	4,411
Dental Assistants (7)	5,240	7,020
Medical Assistants (8)	15,890	18,669
Phlebotomists (7)	2,320	2,833

* Excludes Massage Therapists from analysis. Source:TN Higher Education Commission

Figure 4: Health Sciences In-Demand Wages vs. Non-Health Sciences In-Demand Wages



Source:TN Department of Labor and Workforce Development

Employment in these fields alone is expected to grow by more than 10,000 jobs from 2020 to 2028. This growth is compounded by the fact that there were already more than 10,000 available jobs in these occupational fields posted in 2020. This increased demand is in part due to changing demographic trends with the retiring of the Baby Boomer generation and the general increase in demand for healthcare services brought on by an aging population (Tennessee Higher Education Commission, 2022). In alignment with the earnings trends for STEM classified occupations, health sciences occupations also have higher earnings at all levels as shown in Figure 4.

Lagging Postsecondary Completion

Workforce demands in Tennessee remain strong, and demands for workers in the STEM and health sciences field are growing at faster rates than other occupations. Given this increased demand, it is important to understand how Tennessee postsecondary institutions are responding and preparing students to move into high demand occupational fields in the state.

In 2013, Governor Haslam's Drive to 55 set a goal for 55% of Tennesseans to have earned a postsecondary degree or credential by 2025. Even this target lags estimates of the need. The Lumina Foundation (2023), which specializes in supporting learning after high school found that "by 2025, 60% of adults in the U.S. will need some quality credential beyond high school." While Tennessee has made progress, increasing from 31.8 percent degree attainment in 2009 to 46.8 percent in 2019, recent progress has begun to stall. Figure 5 shows that baccalaureate and sub-baccalaureate degree production in Tennessee have decreased since 2016 (Lumina Foundation, 2023).

IN-DEMAND OCCUPATION SPOTLIGHT:

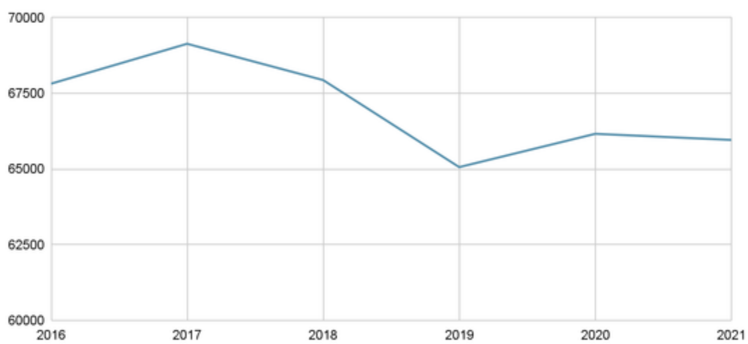
Physician Assistants

- Annual openings (239) eclipse the number of physician assistants graduating from TN programs each year (174 in 2019-20) with the field expected to increase by more than a 1,000 jobs between 2020 and 2028.
- In 2020, Tennessee higher education institutions prepared 174 physician assistants and only 31% of those graduates are employed in Tennessee, leaving a significant gap in the number of needed physician assistants to meet both current and future demand.

Tennessee Higher Education Commission, 2022

Declining postsecondary completion is acutely felt within STEM fields. The pace of STEM job growth far outpaces STEM degree completion. A 2019 state of Tennessee report estimates STEM job growth at 21.6% while STEM program degrees and certifications are collectively down 0.5% from levels experienced between 2016-2020. While other non-STEM programs have seen a greater decrease in degrees and certifications awarded, 0.7% decrease between 2016 and 2020, the overall demand for qualified STEM workers still eclipses the number of Tennesseans completing the necessary degree and certification programs.

Figure 5: Postsecondary Degree Production in Tennessee between 2016-2021



Source:TN Higher Education Commission

ASSESSING PREPARATION FOR CAREERS IN STEM FIELDS AMONG TENNESSEE'S K-12 STUDENTS

Tennessee's K-12 STEM Outcomes Since Race to the Top

The Race to the Top grants awarded by the US Department of Education in 2010 and 2011 included a competitive priority for promoting STEM education. The application specified three elements:

- Offering a rigorous course of study in mathematics, sciences, technology, and engineering (STEM)
- Cooperating with industry experts, museums, universities, and other STEM-capable partners to provide support to educators in integrating STEM content
- Providing applied student learning opportunities with particular emphasis on underrepresented groups and girls/women

While each of these approaches contemplates greater access and availability of courses in science, technology, engineering, and mathematics, "integrating STEM content" appears only in relation to external experts becoming more involved in the K-12 preparation to increase its alignment with industry needs. The Tennessee STEM Innovation Network (TSIN), an outgrowth of the Race to the Top era in Tennessee, focuses on more than just technical courses and frames STEM in the context of pedagogy. According to TSIN, "STEM is more than an acronym. It's a culture of inquiry, productive struggle, & authentic learning" (Tennessee STEM Innovation Network, n.d.).

STEM education serves to build interest and skills in subjects that point toward postsecondary pathways in STEM disciplines and ultimately predict entry into STEM careers. Despite limitations in the ability to measure effective STEM pedagogy emphasizing inquiry and productive struggle, research has shown that K-12 achievement scores in math and science are strong predictors of postsecondary STEM enrollment and subsequent STEM careers (Lichtenberger & George-Jackson, 2013; Leyva et al., 2022; Wiebe et al., 2018; Hinojosa, T. et al., 2016). Self-efficacy in science and mathematics alongside STEM interest correlate strongly with entry into postsecondary STEM courses and subsequent STEM careers. Interest in math and science develops early in the K-12 experience and is often already set by the time students enter high school (Leyva et al., 2022), and student attitudes toward their 9th grade math course correlate strongly with pursuit of postsecondary STEM majors (Quirk, A. et al., 2020). The National Science Board (2022) concluded that "Elementary and secondary education in mathematics and science are the foundation for entry into postsecondary STEM majors and STEM-related occupations."

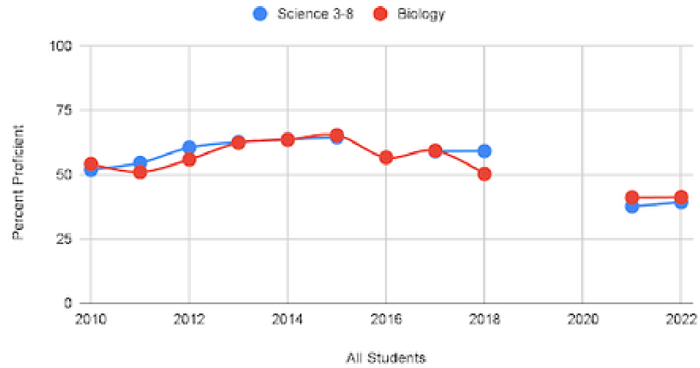
The state of STEM education in Tennessee, then, may be assessed using available math and science achievement data first. Drawing on Tennessee's annual achievement assessments for students in grades 3-8 and the end of high school course tests in Algebra I and Biology offers a clear picture of how Tennessee students perform against state standards both at present and over time. These scores are not comparable across states, however. To enable those comparisons, we also draw on data from the National Assessment of Educational Progress (NAEP). The NAEP is sometimes called "The Nation's Report Card" and uses samples of students in each state to arrive at its measures. Other data, such as Tennessee student results on the ACT math and science sections can also shed light on the state of STEM education in Tennessee, and this data as well as other useful measures form the core of this assessment.

This report examines the performance of Tennessee students in science and mathematics since the Race to the Top award, specifically 2011-2022. In addition, we have examined Tennessee performance data in comparison with that of other states awarded Race to the Top grants. Although a formal national evaluation by Mathematica of the impact of Race to the Top was inconclusive regarding its relationship to student outcomes in math (Dragoset, L. et al., 2016), science scores were not evaluated. A limited, subsequent study conducted as part of a Ph.D. dissertation found that, while mean NAEP science scores increased in all states between the 2009 and 2015 administrations, science means increased faster in states that received Race to the Top grants than those that did not (Petrova, 2018).

TENNESSEE DATA

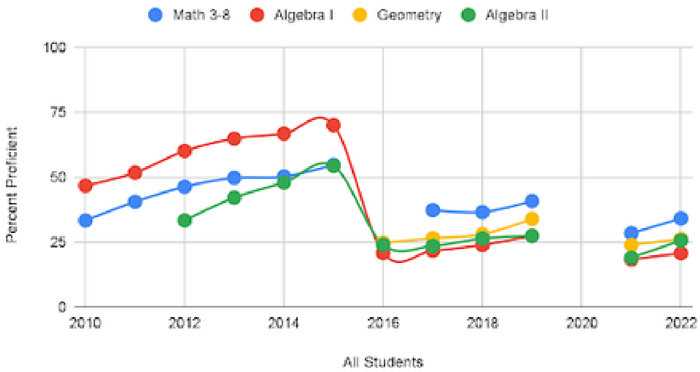
Tennessee student achievement data in measures of both mathematics and sciences showed steady growth between 2010 and 2015. Over that period, the percentage of students in grades 3-8 meeting or exceeding proficiency in math increased by 21.4%. Science proficiency rates in Grades 3-8 rose almost 13 points over that same 5-year period (Fig. 6). Since the high water mark achieved in 2015, Tennessee's proficiency rates on the TCAP/TNReady assessments have declined in all math and science measures across grades 3-8 and including high school end of course examinations in Biology, Algebra I, Geometry, and Algebra II (Fig. 7)

Figure 6: Tennessee science proficiency rates (2010-2022)

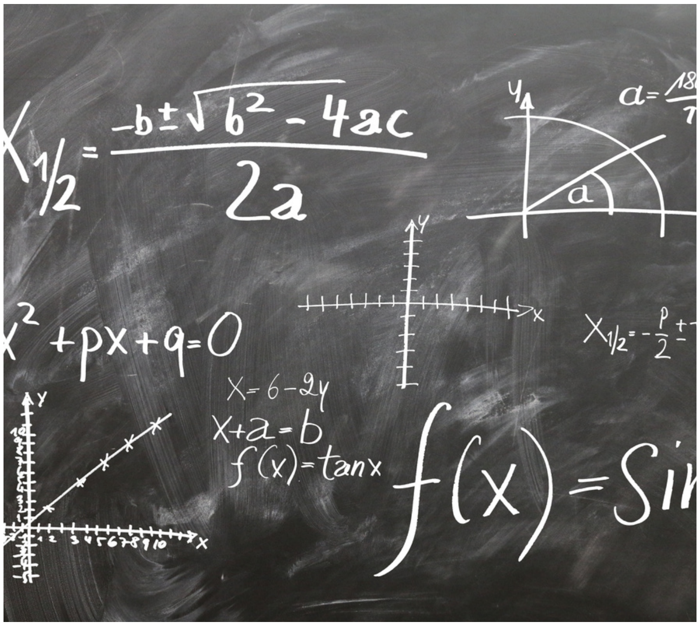


Source:Tennessee Department of Education

Figure 7: Tennessee math proficiency rates (2010-2022)



Source:Tennessee Department of Education



Two significant disruptions are present in Tennessee's achievement test data between 2015 and 2022. The first was Tennessee's adoption of Common Core State Standards (CCSS) (subsequently rewritten and adopted as Tennessee Academic Standards) and the decision to move to online testing using a new assessment, dubbed TN Ready, aligned to the new state standards in 2015. As standards changed, Tennessee also enlisted a new assessment company in 2015. The transition to the new tests was complicated and assessment of students in grades 3-8 was suspended altogether in 2016, resulting in a complete testing gap for students in grades 3-8 that year. High school end of course exams aligned with the new standards showed dramatic declines in proficiency rates that same year with no more than 1 in 4 students achieving proficiency or better on the end of course exams for Algebra I, Geometry, and Algebra II. Once the testing issues were resolved and the new standards were assessed in 2017, proficiency rates, predictably, declined among students in grades 3-8 as well.

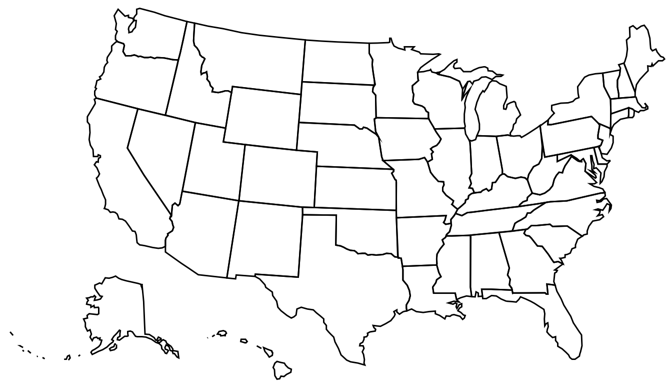
The second disruption, the emergence of COVID-19 and the global pandemic that ensued, resulted in substantially fewer students achieving proficiency in science with over 20 point declines in grades 3-8, and 9 point declines in Biology end of course proficiency as well. Across the board in 2022, only about 2 in 5 students in Tennessee achieved proficiency in grades 3-8 science courses or Biology (Figure 6).

Proficiency rates across all mathematics courses also declined between 2019 and 2021 with some modest gains in grades 3-8 math and Algebra II in the most recent assessment in 2022 (Figure 7).

NATIONAL ASSESSMENT OF EDUCATIONAL PROGRESS (NAEP) DATA

The National Assessment of Educational Progress (NAEP) is sometimes called the Nation's Report Card because of its ability to enable comparable assessments across all the different state jurisdictions. While TNReady is administered to every student each year in Tennessee, its measures are based on state-specific standards and measures that cannot be compared with the performance of students in other states. To accomplish this goal, the NAEP employs a statistical sampling method that tests only selected samples of students in each jurisdiction and uses statistical modeling to arrive at results that can be compared across states. The NAEP is also not administered every year. Instead, the NAEP assesses Reading and Math performance every 2 years, with subjects like science administered less consistently than that. Finally, the NAEP assesses only 4th, 8th, and 12th grade students. Nevertheless, the NAEP data do provide useful insight into the state of STEM education in Tennessee, especially when seeking to understand Tennessee's outcomes in comparison with those in surrounding or other comparable states.

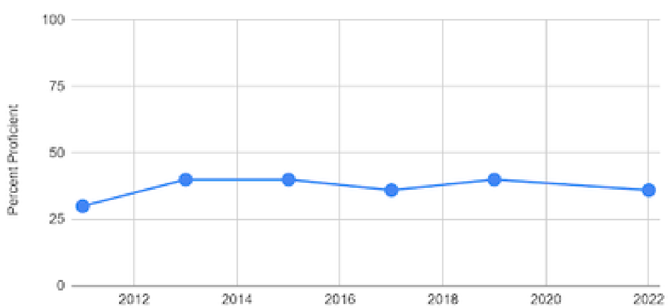
The NAEP last assessed Tennessee students in science in 2015. Prior to that, the NAEP was administered in Tennessee in 2009. Between those two administrations, the percentage of 4th grade students scoring proficient or higher in science rose by 8 points (from 33% to 41%), with average scale scores climbing almost 9 points (148 to 157) eclipsing the national public school average in 2015. Eighth grade science proficiency on the NAEP also rose between 2009 and 2015, adding 9 percentage points to the proficiency rate (28% to 37%). Similarly, average scale scores among 8th grade science students rose 8 points (148 to 156) and moved above the national public school average during that time. These trend lines mirror the steady increases in TCAP science proficiency rates in grades 3-8 over that same 6-year period, except that by Tennessee's relatively lower standards at the time, TCAP showed proficiency rates over 50%.



NAEP mathematics assessments are administered regularly every two years in 4th and 8th grades. The NAEP math results for Tennessee provide an outside look at performance in math that appears remarkably similar to results on Tennessee's annual math assessment data for students in grades 3-8 AFTER Tennessee's standards were strengthened in 2015. Both 4th and 8th grade NAEP math proficiency rates show relative consistency over the 11 years from 2011-2022, with 4th grade rates hovering around 40% (Figure 8) and 8th grade rates around 30% and showing noticeable declines between 2019 and 2022 (4th grade, 4 points; 8th grade, 6 points) (Figure 9).

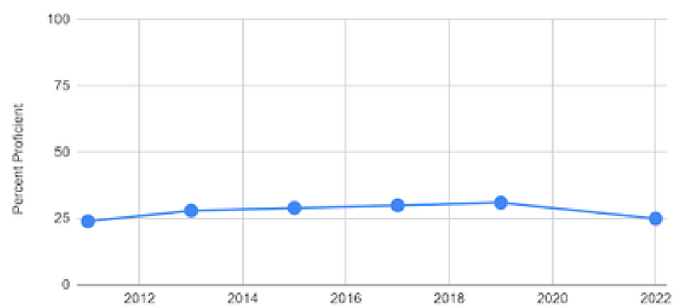
The NAEP scores enable comparisons over time and across jurisdictions. Considering the NAEP math scores from 2011-2022 reveals that, despite some increases in the middle years, a roughly similar percentage of both 4th and 8th grade students in Tennessee achieved proficiency in 2022 as those meeting that mark in 2011. TN Ready scores are administered to all students annually, and the drops in proficiency rates following the adoption of new standards and assessments actually bring the achievement rates among Tennessee's students into closer alignment with the NAEP assessment data over time. Setting these timelines side-by-side leads to the conclusion that math proficiency rates among Tennessee students can best be understood as having held relatively constant, and significantly below half of Tennessee's students achieved proficiency benchmarks over the entire period.

Figure 8: Tennessee NAEP 4th grade math proficiency rates (2011-2022)



Source: NAEP

Figure 8: Tennessee NAEP 8th grade math proficiency rates (2011-2022)

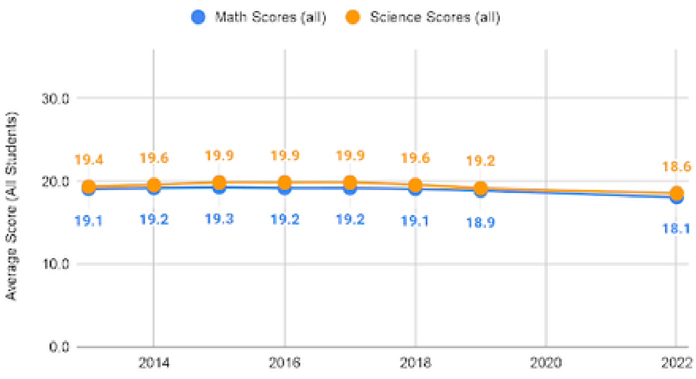


Source: NAEP

COLLEGE ENTRANCE EXAMS (ACT)

While NAEP scores show Tennessee student performance at 4th and 8th grades, ACT scores offer comparable measures of graduating 12th grade students in the state. Unlike NAEP scores that have shown a general trend toward greater alignment with national public school averages since 2013, ACT scores for Tennessee graduates continue to lag behind national averages. Looking specifically at the math and science scores that ACT provides shows that student performance in these subjects has not changed much since 2013. A slight, but generally upward trend in both math and science scores appears from 2013 to 2015, and then scores remain stable in 2016 and 2017, despite a dramatic increase in the number of Tennessee's students taking the ACT beginning in 2016. The final two graduating classes before the pandemic showed declines that erased the earlier gains, and the graduating class of 2022, following the pandemic, showed marked declines. (Figure 10)

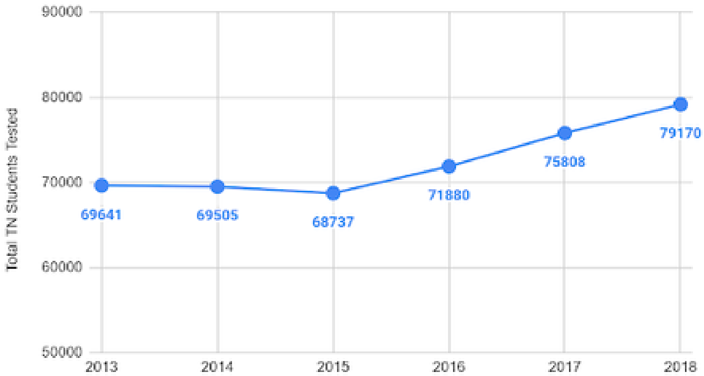
Figure 10: Tennessee ACT Math and Science Scores (2013-2022)



Source: ACT

Not all of the fluctuation since 2016 can be explained by changes in student preparation and performance; however, In 2016, Tennessee added college admission testing as a graduation requirement, and the number of students taking the ACT in the state increased significantly. The number of Tennessee students taking the ACT in 2016 increased by 4.6% over the number tested in the prior year. This climb continued through 2018 with the number of test takers increasing by 5.5% in 2017 and 4.4% in 2018, both compared to the number tested in the prior year. The 79,170 ACT test takers in Tennessee in 2018 represents an increase of 10,433 or 15.2% over the number tested in 2015 before the change (Figure 11). It is surprising that this increase in students taking the ACT had so little effect on the average scores. Conventional wisdom suggests that requiring the test to graduate would draw in a disproportionate number of students not already considering college and likely to have a record of academic achievement that is not as strong. Of course, it is also possible that the new test takers are distributed similarly to the previous pool of test takers and therefore exerted little statistical impact on the numbers. We are not able to determine which scenario is represented in this data, so we are similarly unable to determine a strong relationship between the trend lines in math and science and the state of STEM education in Tennessee.

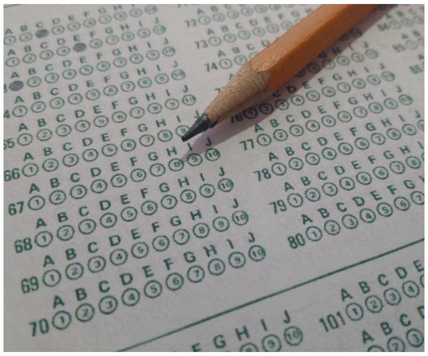
Figure 11: Number of Tennessee Students Taking the ACT (2013-2018)



Source: ACT

Whatever the statistical impact of this policy change, it is clear that ACT math and science scores are significantly lower since the pandemic than they were prior to it. Even though average scores are hard to move, the ACT annually estimates the impact of slight (0.1 points) changes in its overall composite scores on a number of postsecondary indicators. For example, in 2019 ACT ("The Condition of College & Career Readiness 2019: Tennessee Key Findings," 2019) estimated that an increase of 0.1 in the state's average ACT Composite score for the 2019 graduating class would have resulted in:

- 217 more students enrolling in college
- 239 more students persisting to year two
- 284 fewer students needing remedial math in college
- 249 more students persisting to year four
- 260 more students earning a postsecondary degree within six years



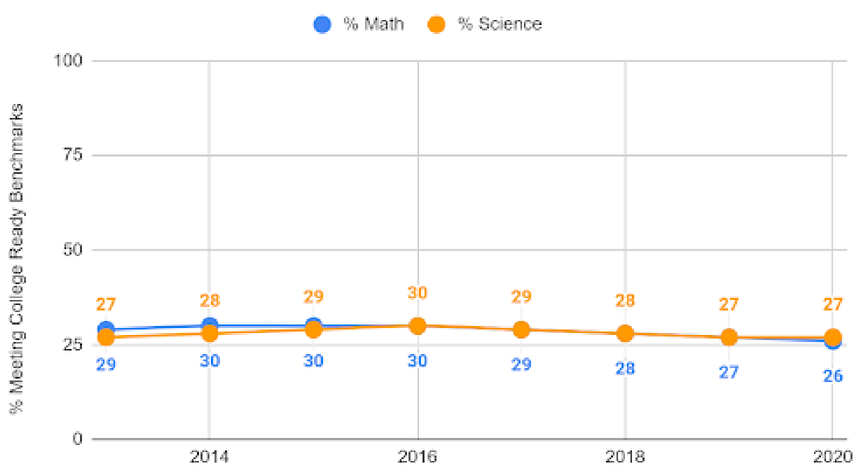
COLLEGE READINESS BENCHMARK (ACT)

Another useful way of looking at ACT data is to consider the percentage of test takers who meet the college ready benchmarks within each subject area. The ACT establishes benchmark scores that represent "the level of achievement required in order to have a 50% chance of obtaining a B or higher or about a 75% chance of obtaining a C or higher in a corresponding credit-bearing college course." In math, the ACT College Readiness benchmark score is 22. At that score, students have a 50% chance of obtaining a B or higher and a 75% chance of obtaining a C or higher in a typical College Algebra Course. In science the ACT college readiness benchmark is 23, and the predictive power of these scores tracks to results in Biology (Allen & Radunzel, 2017).

Applying this metric, available data shows that the percentage of Tennessee students achieving the college ready benchmark in science has held steady and low. The percentage of Tennessee students meeting the college ready benchmarks in science was 27% in 2013 and the same in 2020. In math, the percentage of students meeting the college ready benchmarks actually declined 3 points from 29% in 2013 to 26% in 2020. Two notes about these fluctuations: First, these changes are small in relative terms, and as described above, it is not possible for us to disaggregate the effects of requiring the test for graduation. Second, even though the percentage shifts are small, the increased numbers of test takers does show an impact. Because of the dramatic increase in the number of test takers, 1,972 more Tennessee graduates met the college ready benchmarks in math in 2018 than the number who met them in 2013. In science, 3,365 more students met the benchmarks in 2018 as compared with the number meeting the science benchmark in 2013. While these increases have positive impacts, the overall number of students meeting science and math benchmarks for college readiness still leaves almost 75% of the state's graduating seniors short of the mark for college readiness (Figure 12).

This data overall, paints a fairly consistent picture of the academic proficiency for postsecondary readiness among Tennessee students in math and science, the fields that are most predictive of postsecondary enrollment, persistence and success in courses and majors leading to careers in STEM fields. The picture is one of overall achievement levels that remain fairly flat for the entire period between 2011 and 2022. While annual assessments of all students in Grades 3-8 and high school end of course exam performance show some variation (increases between 2011 and 2015; new standards and assessment tools in 2016; COVID-affected declines 2019-2022), comparison of these more comprehensive measures with the more statistically comparable NAEP assessment as well as results on college admission tests shows that little has changed for Tennessee students since 2011. While we will dig deeper in subsequent sections of this report to understand how student subgroups have fared, the overall picture reveals that K12 preparation of Tennessee students for postsecondary enrollment in majors leading to careers in STEM fields has not improved markedly in the last 11 years.

Figure 12: Tennessee ACT College Ready Benchmarks Met (2013-2020)



Source: ACT

Tennessee's K-12 STEM Outcomes Since Race to the Top: Associated Findings

- Tennessee's students showed improvement in STEM-related academic outcomes from 2009-2015; however, when comparing Tennessee Assessment Data (TCAP/TN Ready) with NAEP sampling data, those gains appear more closely linked with Tennessee's relatively less rigorous standards prior to adoption and assessment of first the Common Core State Standards (CCSS) and then the new Tennessee State Standards adopted in 2015. Accounting for the shift in standards and assessments, the most likely conclusion is that we can discern marginal improvement across all K12 public school students in Tennessee between 2011 and 2022.

- With Tennessee's new standards in place, some data may show slow, positive gains in student outcomes between 2016 and 2019, but there are too few data points from that brief period to indicate a positive trend.

- Almost all assessment data that is comparable between 2019 and 2021/2022 show declining performance associated with the many academic disruptions due to the global COVID-19 pandemic.

- More specific metrics are needed. While math and science assessments and college admission exams show strong correlation with matriculation, persistence, and graduation in postsecondary STEM fields, the data is inexact and incomplete for assessing alternative pathways into STEM careers and contributes to further isolation among STEM fields when integration and problem-solving skills across the disciplines are increasingly necessary. Considering career and technical education pathways, TCAT and community college entry points, as well as traditional 4-year college paths will require a richer set of data points and benchmarks in order to promote real data-driven improvement for Tennessee's students and improved workforce development efforts for Tennessee as a state.

- Aligned and consistent testing plays an important role. Tennessee's experiences with testing since 2015 have produced gaps and uncertainties that make data-driven decisions more difficult. Some of these disruptions resulted from needed improvements in science and math standards, but some also resulted from technical shortcomings as well as COVID-19. Regardless of the causes, trend data and consistent comparable analysis enables planning and course adjustments that are not possible when data is incomplete or inconsistent.

HIGHLIGHTS

Marginal improvement in STEM outcomes (2011-2022)

New standards associated with possible, positive gains (2016-2019)

COVID-19 pandemic drove achievement declines (2019-2022)

More STEM-Specific metrics needed

Aligned and consistent testing needed will yield better understanding of trends and outcomes

UNDERSTANDING TENNESSEE'S RELATIVE K12 STEM PREPARATION ACROSS COMPARABLE STATES

We turn our attention now to the relative academic preparation among Tennessee's K12 students in comparison with the academic preparation among students in other states. Using NAEP data and selected comparison states enables us to see how changing academic indicators over time also enable us to identify states according to their overall performance as compared to the National Public Schools average performance and compared to one another.

Considering the percent of students achieving proficient or advanced scores on NAEP Math assessments, Tennessee's relative ranking against other states has climbed significantly since 2011, and although the percentage of students achieving proficient or advanced scores declined during COVID, Tennessee's declines were slower than other states, causing its relative ranking to continue climbing. While Tennessee was ranked 47th in 4th grade math proficiency and 48th in 8th grade math proficiency in 2011, by 2022 Tennessee's results ranked 23rd in 4th grade math and 26th in 8th grade math. (Figure 13)

Figure 13: Tennessee Rankings
NAEP math proficiency rates (2011-2022)

Tennessee Rankings NAEP Math (2011-2022)						
	2011	**2013**	**2015**	**2017**	**2019**	**2022**
4th Grade Math	48th	32nd	26th	35th	25th	23rd
8th Grade Math	47th	43rd	38th	35th	31st	26th

Source: NAEP

While this improvement may appear to be cause for celebration, the data shows that the improvements in Tennessee's relative outcomes were not associated with similarly dramatic improvements for student outcomes. Unfortunately, the improved rankings tell us more about performance changes in other states, and while improving faster than other states (or even declining slower) can represent a comparative advantage, the percentage of Tennessee's students meeting standards in math has remained largely unchanged.

Considering statistically significant differences, the percentage of Tennessee students in both 4th and 8th grade scoring at proficient or above on the NAEP was significantly lower than the National Public average in 2011. In 2013 and 2015, Tennessee's 4th grade math students achieved proficiency at a rate not statistically different from the National Public School rate, and while 4th grade proficiency rates fell below the National Public rate in 2017, the NAEP results for both 2019 and 2022 show Tennessee students returning to the National Public School average level of performance. The 8th grade trends were similar with proficiency rates for Tennessee's 8th grade math students falling significantly below the National Public school rates in 2011 and 2013 and again in 2017. However, in 2015 and most recently in 2019 and 2022, Tennessee's 8th grade math students achieved proficiency at rates not statistically different from the National Public school rates. Certainly, Tennessee's students have shown improvement in NAEP math proficiency rates since 2011. Beginning at a level significantly below the National Public school rates, Tennessee's students now achieve at levels statistically similar to the National Public school rates, and that improvement seems to have held through COVID, where Tennessee's declines were generally shallower than the declines experienced in many other states.

A snapshot of this trend is evident in the average scale scores on the 4th Grade Math NAEP. Between 2011 and 2022, Tennessee's 4th grade math students added 3 points to their scale score, but between 2011 and 2019 those same scale scores climbed 7 points. Between 2019 and 2022, the disruptions from COVID created a 4 point decline in 4th grade math scores. A similar trend can be seen by looking at scale scores among students at different proficiency levels, as seen in Figure 14. However, students assessed as achieving proficiency grew more prior to the pandemic than students at basic or below basic levels.

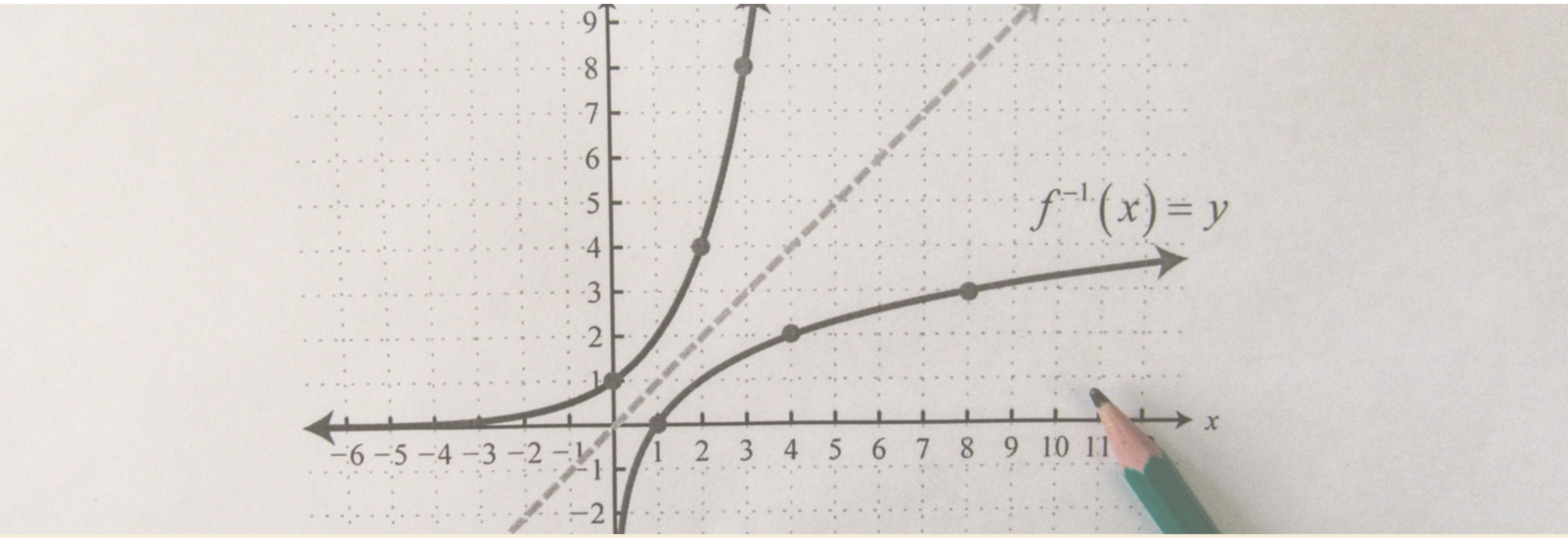
Figure 14: Tennessee NAEP 4th grade math scale score changes before and since the PandemicTennessee 4th Grade Math (NAEP)

Tennessee 4th Grade Math (NAEP)	Change 2011-2022	Change 2011-2019	Change 2019-2022
Overall Scale Scores	3	7	-4
% Proficient or Advanced	6	10	-4
% Below Basic	-1	-4	3
% Basic or Higher	0	4	-4

Source: NAEP

Race to the Top State Comparisons

Race to the Top awards were granted to 18 states and the District of Columbia over 3 rounds. Delaware and Tennessee were the only two awarded in the first round, and Tennessee's $500M award was significantly larger than Delaware's $100M. The 10 second round awards were aligned to the size of the jurisdiction with Florida and New York receiving $700M, Georgia, North Carolina, and Ohio receiving $400M, Maryland and Massachusetts receiving $250M, and DC, Hawaii, and Rhode Island receiving $75M. The third round consisted of substantially smaller awards ranging from $17M (Kentucky and Louisiana) to $38M (New Jersey). Arizona ($25M), Colorado ($18M), Illinois ($43M), and Pennsylvania ($41M) complete the list of third round awards.



Only 4 Race to the Top jurisdictions showed a higher percentage of 4th grade math students assessed as proficient or advanced in 2022 than they showed in 2011 (DC, Florida, Louisiana, and Tennessee). Of those 4, Tennessee's rate grew the most (+6), with Florida's increase (+4) just 2 points behind Tennessee's. The national average rate remained relatively flat from 2011-2019 but declined 5 points during COVID. Washington DC experienced a double digit decline during COVID (-10), erasing almost all of its gains between 2011 and 2019. Five states experienced double digit declines in 4th Grade math proficiency rates over the entire period (2011-2019), with declines before and during COVID roughly similar in Maryland and Massachusetts. Colorado and New Jersey lost about twice as much during COVID as they lost between 2011 and 2019, and Delaware's 13 point loss showed up entirely during COVID. (Figure 15)

Figure 15: Race to the Top States NAEP 4th grade math proficiency rates (2011-2022)

NAEP Fourth Grade Mathematics Proficiency (percent), by state/jurisdiction: 2009–2019							Percentage Change Before/ After COVID		
Jurisdiction	2011	2013	2015	2017	2019	2022	RTTT Era (2011-2022)	Pre-COVID (2011-2019)	Post-COVID (2019-2022)
National	40	42	40	40	41	36	-4	1	-5
Arizona	34	40	38	34	37	32	-2	3	-5
Colorado	47	50	43	42	44	36	-11	-3	-8
Delaware	39	42	37	36	39	26	-13	0	-13
District of Columbia	22	28	31	32	34	24	2	12	-10
Florida	37	41	42	48	48	41	4	11	-7
Georgia	37	39	35	35	36	34	-3	-1	-2
Hawaii	40	46	38	38	40	37	-3	0	-3
Illinois	38	39	37	39	38	38	0	0	0
Kentucky	39	41	40	40	40	33	-6	1	-7
Louisiana	26	26	30	27	29	27	1	3	-2
Maryland	48	47	40	42	39	31	-17	-9	-8
Massachusetts	58	58	54	53	50	43	-15	-8	-7
New Jersey	51	49	47	50	48	39	-12	-3	-9
New York	36	40	35	35	37	28	-8	1	-9
North Carolina	44	45	44	42	41	35	-9	-3	-6
Ohio	45	48	45	41	41	40	-5	-4	-1
Pennsylvania	48	44	45	44	47	40	-8	-1	-7
Rhode Island	43	42	37	39	40	34	-9	-3	-6
Tennessee	30	40	40	36	40	36	6	10	-4

NOTE: Some apparent differences between estimates may not be statistically significant.
SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2011, 2013, 2015, 2017, 2019, and 2022 Mathematics Assessments.

LEGEND

Equal to Tennessee	Above Tennessee	Below Tennessee

The trends in 8th grade math were even more pronounced with only Tennessee showing higher rates of proficiency in 2022 than in 2011, although the gain was only 1%. From 2011-2019, Tennessee added 7 percentage points to its proficiency rates in 8th grade math, losing 6 points during COVID. Tennessee's 7 point gain before COVID was the greatest among this group, and only Louisiana and Rhode Island showed less COVID learning loss than Tennessee across these Race to the Top States. (Figure 16)

Figure 16: Race to the Top States NAEP 8th grade math proficiency rates (2011-2022)

NAEP Eighth Grade Mathematics Proficiency (percent), by state: 2009–2019							Percentage Change Before/ After COVID		
Jurisdiction	2011	2013	2015	2017	2019	2022	RTTT Era (2011-2022)	Pre-COVID (2011-2019)	Post-COVID (2019-2022)
United States	34	34	32	33	33	26	-8	-1	-7
Arizona	31	31	35	34	31	24	-7	0	-7
Colorado	43	42	37	38	37	28	-15	-6	-9
Delaware	32	33	30	28	29	18	-14	-3	-11
District of Columbia	17	19	19	21	23	16	-1	6	-7
Florida	28	31	26	29	31	23	-5	3	-8
Georgia	28	29	28	31	31	24	-4	3	-7
Hawaii	30	32	30	27	28	22	-8	-2	-6
Illinois	33	36	32	32	34	27	-6	1	-7
Kentucky	31	30	28	29	29	21	-10	-2	-8
Louisiana	22	21	18	19	23	19	-3	1	-4
Maryland	40	37	35	33	33	25	-15	-7	-8
Massachusetts	51	55	51	50	47	35	-16	-4	-12
New Jersey	47	47	46	44	44	33	-14	-3	-11
New York	30	32	31	34	34	28	-2	4	-6
North Carolina	37	36	33	35	37	25	-12	0	-12
Ohio	39	40	35	40	38	29	-10	-1	-9
Pennsylvania	39	39	36	38	39	27	-12	0	-12
Rhode Island	34	36	32	30	29	24	-10	-5	-5
Tennessee	24	28	29	30	31	25	1	7	-6

NOTE: Some apparent differences between estimates may not be statistically significant. SOURCE: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2011, 2013, 2015, 2017, 2019, and 2022 Mathematics Assessments.

LEGEND

Equal to Tennessee	Above Tennessee	Below Tennessee

The implications for science education in Race to the Top states have been under investigated. Mathematica was tasked with conducting the main evaluations of the effect of Race to the Top and School Improvement Grants on both adoption of RTT-promoted policies and student outcomes. However, the Mathematica report only considered NAEP Reading and Math scores in its analysis and concluded that "The relationship between RTT and student outcomes was not clear. Trends in student outcomes could be interpreted as providing evidence of a positive effect of RTT, a negative effect of RTT, or no effect of RTT" (Dragoset, L. et al., 2016).

There are several reasons why science scores were not directly investigated, including the relatively less frequent administration of the NAEP in science and a general research-based conclusion that reading and math scores are generally predictive of scores in science as well (Petrova, 2018). A subsequent analysis conducted as a dissertation study and using NAEP science scores from 2009 and 2015 showed that while 4th and 8th grade science students made progress in both RTT and non-RTT states, "the RTTT states group displayed a higher percentage increase of its average science score" (Petrova, 2018). While this study claims no more of a causal relationship than the Mathematica evaluation was able to uncover, it does suggest that including the available NAEP science scores for Tennessee might also be useful in understanding the state of STEM education in Tennessee.

LEGEND	Equal to Tennessee	Above Tennessee	Below Tennessee

Figure 17: Race to the Top States NAEP 4th and 8th grade science proficiency rates (2009-2015)

Fourth Grade NAEP Science Proficiency (percent), by state: 2009–2015			
State	2009	2015	
United States	32	37	
Delaware	34	33	
District of Columbia	NA	NA	
Florida	32	42	
Georgia	27	35	
Hawaii	25	30	
Kentucky	45	44	
Louisiana	25	NA	
Maryland	33	37	
Massachusetts	45	47	
New York	30	33	
North Carolina	30	36	
Ohio	41	41	
Rhode Island	34	36	
Tennessee	33	41	
Legend	Equal to Tennessee	Above Tennessee	Below Tennessee

Eighth Grade NAEP Science Proficiency (percent), by state: 2009–2015			
State	2009	2011	2015
United States	29	31	33
Delaware	25	28	29
District of Columbia	NA	8	NA
Florida	25	28	33
Georgia	27	30	31
Hawaii	17	22	23
Kentucky	34	34	35
Louisiana	20	22	NA
Maryland	28	32	36
Massachusetts	41	44	44
New York	31	29	30
North Carolina	24	26	31
Ohio	37	38	38
Rhode Island	26	31	32
Tennessee	28	31	37
Legend	Equal to Tennessee	Above Tennessee	Below Tennessee

NA = not available. NOTES: The National Assessment of Educational Progress (NAEP) scores are for public schools only. The national value for the United States is the reported value in the NAEP reports and does not include U.S. territories. SOURCE: National Center for Education Statistics, National Assessment of Educational Progress (various years).

Between the 2009 and 2015 NAEP administrations, Tennessee's 8th and 4th grade students did show significant gains in science. Tennessee's 4th grade students improved their proficiency rate by 8 percentage points between 2009 and 2015, and 9 percent more 8th grade students assessed as proficient or advanced in 2015 as compared with the rate in 2009. In 8th grade, an additional administration for 8th grade students shows that ⅔ of the 9 points gained between 2009 and 2015 occurred after 2011. (Figure 17) It is certainly possible that the state's focus on STEM education flowing out of the Race to the Top award could have played a positive role in these gains, but no causal or statistically significant correlation can be determined from the available data.

Tennessee's Relative STEM Performance Among Race to the Top States: Associated Findings

- Tennessee students generally improved more rapidly than students in Race to the Top comparison states from 2011-2019 (last pre-COVID data).
- During COVID, Tennessee proficiency rates declined less than the rates in Race to the Top Comparison states.
- The NAEP Assessment shows proficiency rates in other Race to the Top states declining significantly more than Tennessee's rates both before COVID and even more significantly during COVID. As a result, Tennessee's math outcomes are now statistically similar to the average proficiency rates among national public schools, and the state's relative rankings have improved, even while its proficiency rates have remained flat.

HIGHLIGHTS

Tennessee proficiency rate improved faster than many Race to the Top States

Tennessee's COVID learning loss was less than most Race to the Top States

Tennessee STEM performance has risen to the national public school average (NAEP)

UNDERSTANDING PERSISTENT INEQUITIES: Which Students are Persistently Left Behind?

While the standardized measures that shape this analysis only tell part of the story when it comes to understanding the state of STEM education in Tennessee, the clear and consistent reality is that since Tennessee shifted to new state standards that are comparable with the requirements that students in other states also pursue, there has not been a year when more than half of Tennessee's students have attained proficiency in math or science. In fact, seldom have more than one in three Tennessee students attained proficiency on measures of science or math achievement whether measured by Tennessee's annual assessments (TN Ready) or by the NAEP. When it comes to preparing Tennessee K-12 students for postsecondary studies or other pathways leading to careers in STEM fields, well over half of the state's students are being left behind.

Furthermore, the COVID-19 pandemic widened the racial, gender, and socioeconomic disparities in STEM education and the STEM workforce nationally.

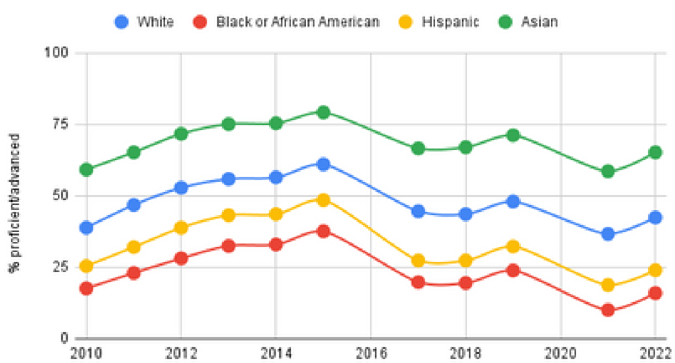
> *COVID-19 substantially impacted the global economy, including the U.S. S&E enterprise. In the United States, the pandemic exacerbated pre-existing socioeconomic differences, such as a lack of access to computers and broadband at home for low-income and some minority students. The unemployment rate of STEM workers was lower than that of non-STEM workers, but women in STEM experienced higher unemployment than their male counterparts. Lack of access to technology for online learning was reported at higher rates for some minority groups. Enrollment at community colleges that serve low- income students declined sharply. The experience of the pandemic highlights challenges to the U.S. S&E enterprise, such as improving access to high-quality online education, while simultaneously showing the responsiveness of U.S. S&T capability in rapidly developing effective COVID-19 vaccines (National Science Board, 2022, p. 3).*

RACE: TN READY DATA

Moving beyond the aggregate averages in the previous section, we quickly see the largest impact of this overall under-preparation for future STEM careers falls on Black and Latino/Latina students and students whose families experience lower socioeconomic situations. Assessment data consistently reveals that race is associated with wide and consistent differences in assessed proficiency rates. For example, since Tennessee adopted more rigorous academic standards in 2015, White students have attained proficiency at rates nearly 25 percentage points (165%) greater than Black students in Math, grades 3-8. Similarly, White students have attained proficiency at rates around 16-18 percentage points (76%) greater than Hispanic students. (Figure 18)

Figure 18: Racial Disparities in Grades 3-8 math (2017-2022)

TENNESSEE MATHEMATICS (TN Ready) Grades 3-8					
Proficiency Rate Differences	2017	2018	2019	2021	2022
White: Black	24.8	24.1	24.1	26.6	26.4
White: Hispanic	17.2	16.2	15.7	17.9	18.4



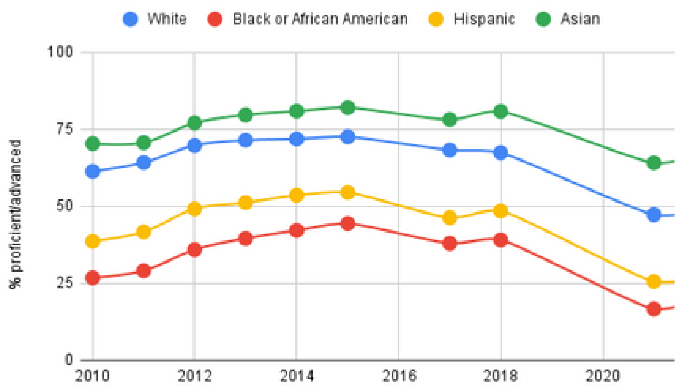
Source: Tennessee Department of Education

In Science across grades 3-8, Tennessee students identifying as White attained proficiency at rates nearly 30 percentage points (144%) greater than Black students, and around 20 percentage points (80%) greater than Hispanic students. (Figure 19)

These same disparate patterns show up in high school end of course proficiency exams as well. In Algebra, Tennessee students identifying as White attained proficiency at rates around 20 percentage points (248%) greater than Black students, narrowing slightly following COVID, and around 12 percentage points (91%) greater than Hispanic students over this same period. (Figure 20)

Figure 19: Racial Disparities in Grades 3-8 science (2017-2022)

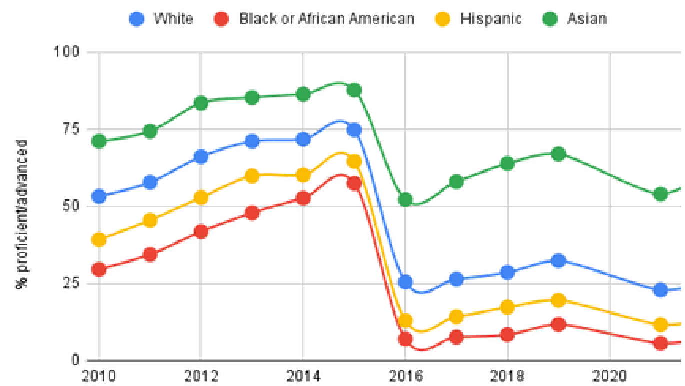
TENNESSEE SCIENCE (TN Ready) Grades 3-8				
Proficiency Rate Differences	2017	2018	2021	2022
White: Black	30.3	28.3	30.6	28.6
White: Hispanic	22.0	18.9	21.7	21.5



Source: Tennessee Department of Education

Figure 20: Racial Disparities in Algebra I (2017-2022)

TENNESSEE ALGEBRA 1 (EOC Exam)					
Proficiency Rate Differences	2017	2018	2019	2021	2022
White: Black	18.8	20.2	20.7	17.3	18.1
White: Hispanic	12.2	11.3	12.8	11.3	12.1

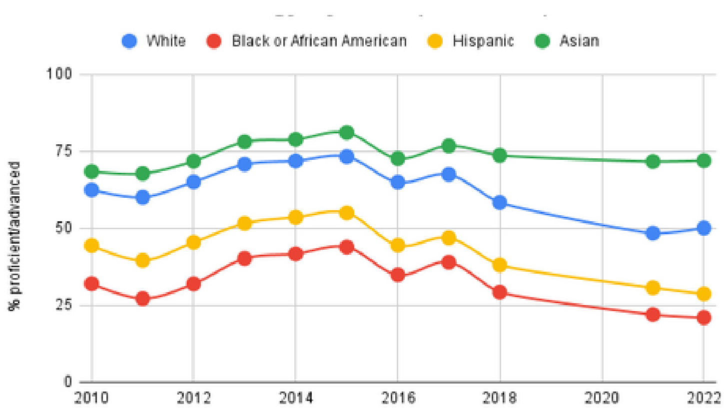


Source: Tennessee Department of Education

Wide variation shows up in Biology. Tennessee students identifying as White attained proficiency at rates near 29 percentage points (139%) greater than Black students, slightly narrower in 2021, and around 20 percentage points (75%) greater than Hispanic students over this same period with a similarly slight narrowing in 2021. (Figure 21)

Figure 21: Racial Disparities in Biology (2017-2022)

TENNESSEE Biology (EOC Exam)				
Proficiency Rate Differences	2017	2018	2021	2022
White: Black	28.5	29.1	26.4	29.1
White: Hispanic	20.6	20.3	17.7	21.4



Source: Tennessee Department of Education

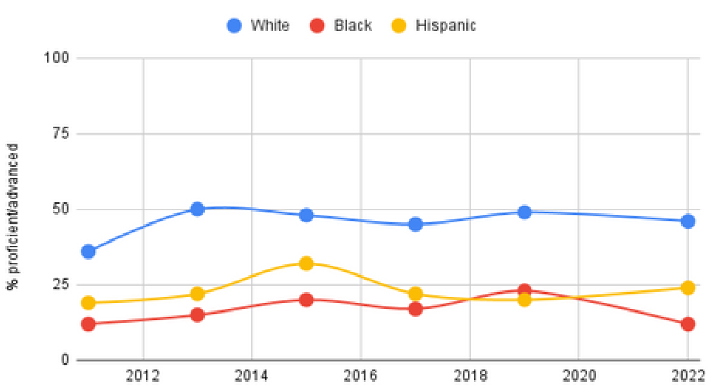
RACE: NAEP DATA

NAEP data on Tennessee's proficiency rates show similarly large differences associated with race. Extending the period of analysis, since the NAEP standards have remained consistent and comparable over time reveals that Tennessee students identifying as White attained proficiency in 4th Grade Math at rates 34 percentage points (283%) greater than Tennessee students identifying as Black in 2022. Additionally, this White to Black student proficiency rate difference has grown by 10 percentage points with the proficiency rate among students identifying as Black remaining constant at 12% since 2011. Among 4th grade Tennessee students identifying as Hispanic, the proficiency rate difference when comparing to proficiency rates of White students has increased by 5 percentage points % since 2011. In 2022 the White:Hispanic proficiency rate difference of 22 percentage points equates to a 92% greater rate among students identifying as White compared with students identifying as Hispanic. (Figure 22)

NAEP eighth grade math proficiency rates show similar differences over the same time period with proficiency rates for 8th grade students identifying as Black trailing the proficiency rates among white students by around 20-25 percentage points widening to 24 percentage points (300% greater) in 2022 after declining proficiency rates among both groups of students with those of Black students declining further during the pandemic. Eighth grade students identifying as White also attained proficiency rates 146% greater than rates among their Hispanic peers. (Figure 23)

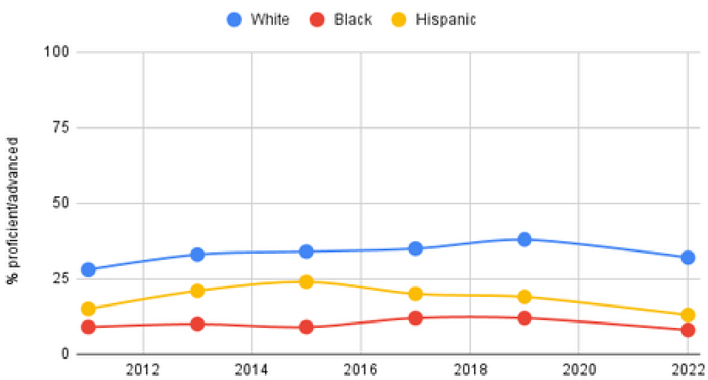
Figure 22: Racial Disparities in NAEP 4th grade math (2011-2022)

TENNESSEE 4th Grade MATHEMATICS (NAEP)						
Proficiency Rate Differences	2011	201 3	201 5	201 7	2019	202 2
White: Black	24	35	28	28	26	34
White: Hispanic	17	28	16	23	29	22



Source: NAEP

Figure 23: Racial Disparities in NAEP 8th grade math (2011-2022)

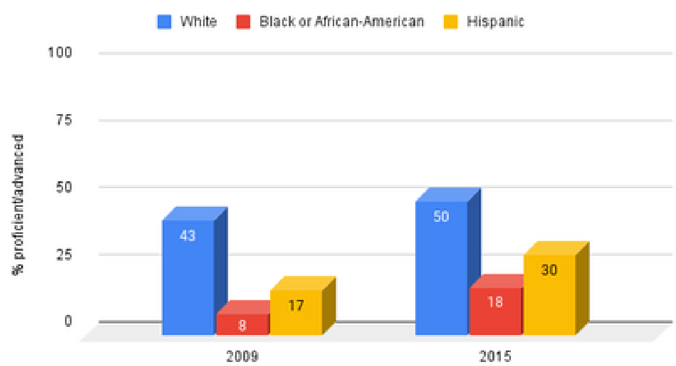


TENNESSEE 8th Grade MATHEMATICS (NAEP)						
Proficiency Rate Differences	2011	201 3	201 5	2017	2019	202 2
White: Black	19	23	25	23	26	24
White: Hispanic	13	12	10	15	19	19

Source: NAEP

Tennessee 4th grade students were only assessed in science in the years 2009 and 2015, but the differences in proficiency rates are even more pronounced. In 2009, only 8% of Black students in Tennessee achieved proficiency, a full 35 percentage points less than proficiency rates among their White peers. Little change appeared in these disparities between 2009 and 2015 when White students achieved proficiency at rates 32 percentage points greater than their Black peers. Slightly narrower proficiency rate differences were evident between 4th grade students identifying as Hispanic who achieved proficiency at rates 26 percentage points lower than those of their White peers in 2009, narrowing only to a 20 percentage point difference in 2015. (Figure 24)

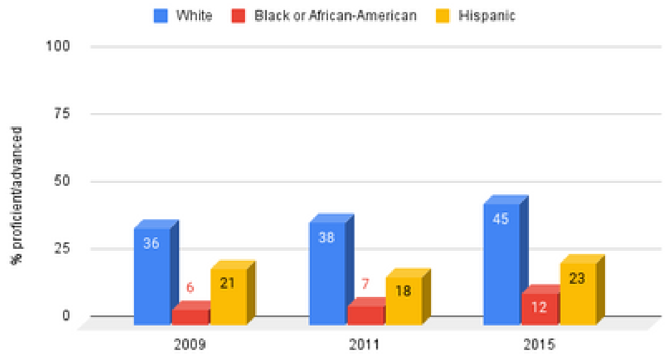
Figure 24: Racial Disparities in NAEP 4th grade science (2009-2015)



Source: NAEP

Although the NAEP assessment also calculated science proficiency rates among Tennessee's 8th grade students in 2011, in addition to 2009 and 2015, the patterns remained the same. Proficiency rates among white students were 30% higher than those among Black students in 2009, growing to 31% in 2011 and 33% in 2015. Rates of science proficiency among 8th grade students who identify as Hispanic in Tennessee were higher and therefore closer to the proficiency rates among their white peers, but still significantly lower by 15% in 2009, climbing to 20% in 2011 and 22% in 2015. (Figure 25)

Figure 25: Racial Disparities in NAEP 8th grade science (2009-2015)



Source: NAEP

Considering these proficiency rate disparities, let's not lose sight of two important facts. First, lower proficiency rates correlating with racial identities is not an indication of ability or other deficiencies among students whose identities align with consistently marginalized groups. We will discuss some of the potential explanations below, but most of them represent the outcomes of a system structurally designed to favor whiteness over other racial identifiers. Secondly, these science proficiency rates show that the overwhelming majority of students of color are not being well-prepared for careers in STEM. The highest science proficiency rate among Black students shows that only 18%, fewer than 1 in 5 4th grade students, assessed as proficient and only 12%, or 1 in 8 of Tennessee's 8th grade students were prepared enough to attain proficiency in science. While significant time has passed since Tennessee's last NAEP Science assessment in 2015, the other data in this report, including Tennessee's own annual data above suggests that the situation has not improved significantly.

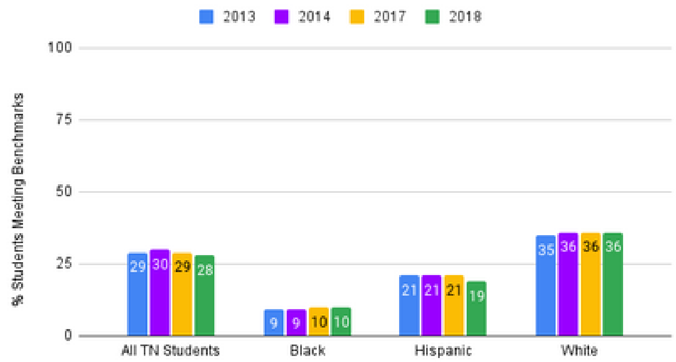
The Nation's Report Card

RACE: COLLEGE ENTRANCE EXAM DATA (ACT)

The ACT college-ready benchmark scores enable us to look at the percentages of Tennessee's students who are well-prepared for post-secondary pathways in STEM fields. This college readiness data reveals similar large disparities between Tennessee's White students and its students of color. In math, White students in Tennessee met ACT college-ready benchmarks at a rate just over 1 in 3. While a college readiness rate of 1 in 3 students is still quite low, college readiness rates in math among Hispanic students were around 1 in 5 over the past decade while college readiness rates in math among Black students in Tennessee never moved above 1 in 10. (Figure 26)

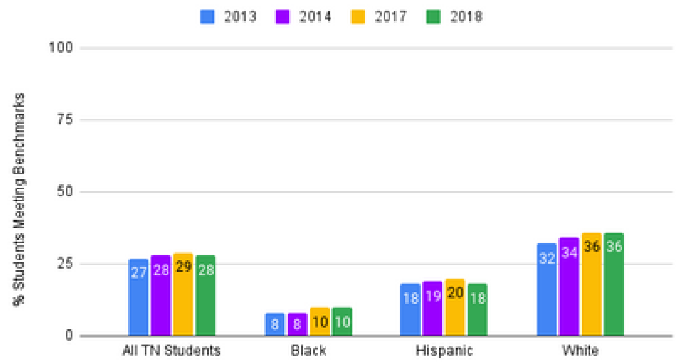
Similarly, the ACT college-ready benchmark in science shows slightly more than 1 in 4 Tennessee students who took the ACT attained a science score that prepares them well for success in future college STEM courses, especially biology. The inequities in science data are similar to those in math. Among white students taking the ACT, just over 1 in 3 shows college readiness in science, while Tennessee's Hispanic students achieved college-ready scores in science at rates slightly lower than they did in math. In science, Hispanic students achieved the college-ready benchmark at 18% in 2013 and in 2018. In science as in math, Tennessee's Black students who took the ACT achieved a college-ready score at a rate that peaked at 10%. (Figure 27)

Figure 26: Racial Disparities in ACT math college readiness (2013-2018)



Source: ACT

Figure 27: Racial Disparities in ACT science college readiness (2011-2022)

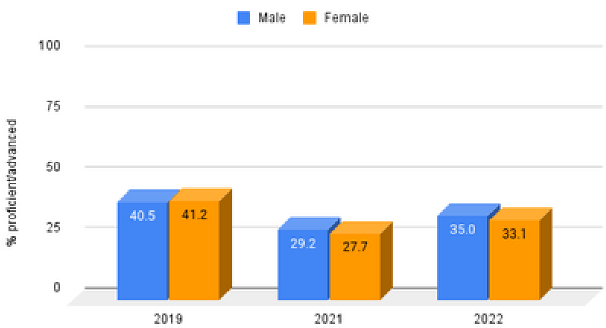


Source: ACT

GENDER: TENNESSEE DATA

Historical variation in STEM subjects, postsecondary majors, and careers by gender also bears examination, and the data alone does not show significant differences in proficiency between male and female students. In some cases, female students in Tennessee out performed their male counterparts in terms of their proficiency rates. For example, TN Ready Math proficiency among Tennessee students in grades 3-8 show females achieving proficiency at rates .7% greater than those of male students. However, post-pandemic data shows male proficiency rates among 3rd-8th graders surpassing those of female students by 1.5% in 2021 and almost a full 2% in 2022. (Figure 28)

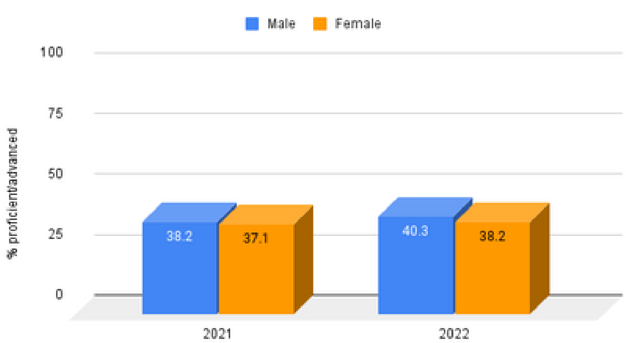
Figure 28: Gender Disparities in grades 3-8 math (2019-2022)



Source: Tennessee Department of Education

In Tennessee Science proficiency rates, male students achieved proficiency at a rate 1% higher than females in 2021 and 2% higher than females in 2022. (Figure 29)

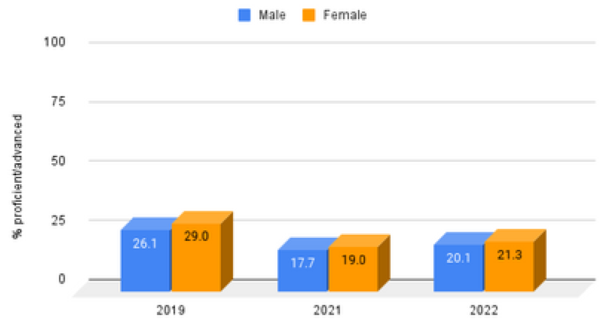
Figure 29: Gender Disparities in grades 3-8 science (2021-2022)



Source: Tennessee Department of Education

Algebra end of course exams in Tennessee show female students attaining proficiency at higher rates than males, although the gap narrowed during the pandemic, even as overall proficiency rates hovered near 1 in 5. (Figure 30)

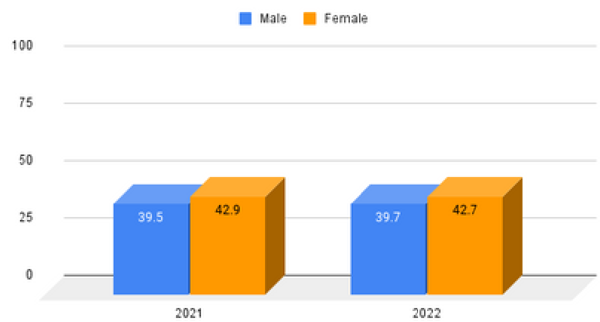
Figure 30: Gender Disparities in Algebra I (2019-2022)



Source: Tennessee Department of Education

Likewise, female student proficiency rates surpassed male proficiency rates on the Biology end of course exams as well. (Figure 31)

Figure 31: Gender Disparities in Biology (2021-2022)



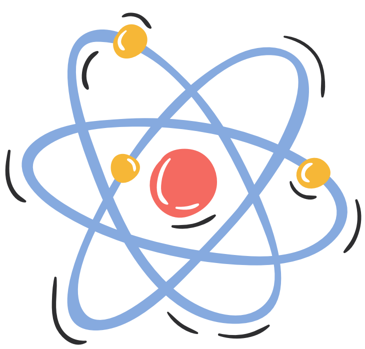
Source: Tennessee Department of Education

Despite relatively similar proficiency levels between male and female students in K-12 achievement measures, the workforce realities continue to reflect substantial gender gaps. The National Science Board (2022) reported that nationally, "Women make up about one-third of the STEM workforce, less than their representation in the employed U.S. population (48%)." While the "share of women in STEM grew from 32% in 2010 to 34% in 2019," that wide disparity continues, and COVID-19 slowed or reversed this progress (National Science Board, 2022, p. 12).

Seeking to understand more about these disparate effects, Quintana and Saatcioglu (2022) have explored development of early "identities" on subsequent educational and career pursuits, and they found that "early-acquired attitudes have a direct effect on future college and career outcomes, independent of more recent attitudes. In fact, we suggest that this interpretation is implied by the commonly held claim that early-life attitudes and experiences have a key determining influence in individuals' career trajectories." Exploring this and other research to elucidate our deeper understanding of the causes of disparate entry into STEM careers will be a focus of our Phase II report in addition to identifying potential interventions to consider based on available research such as this.

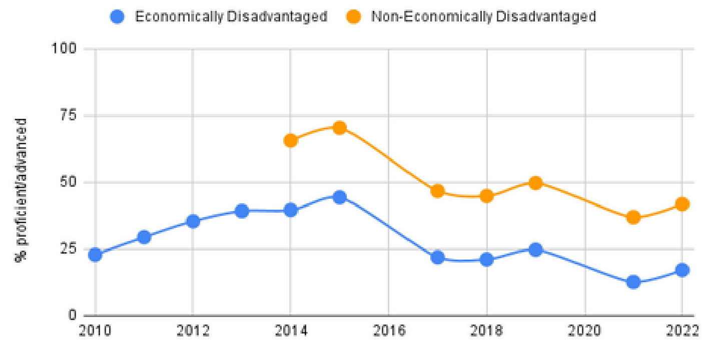
SOCIOECONOMIC STATUS: TENNESSEE DATA

Indicators of socioeconomic status have always presented troubling identifier challenges. The Federal Government and Tennessee Department of Education have historically used eligibility for free or reduced price lunches as a very rough identifier of family socioeconomic status, and numerous changes to the eligibility requirements for the National School Lunch Program have added instability in the data over the past 10 years. While this means that comparisons year-to-year may be taken with a grain of salt, it is still possible to deduce comparative outcomes between students who qualified for the program and those who did not within any given year, since students identified in a single year would be identified using the same standard, so that considering disparate outcomes is possible, even though comparing those disparate outcomes year-to-year is somewhat less reliable.



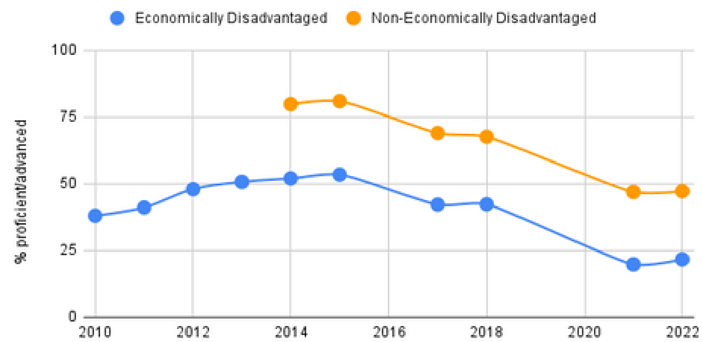
With these caveats in mind, Tennessee math and science data for students in grades 3-8 reveals persistent and steady difference in proficiency rates for students identified by the state as economically disadvantaged achieving math proficiency at rates lower than 1 in 4 since the adoption of new standards. Those not classified as economically disadvantaged achieved proficiency rates closer to 1 in 2 over the same time period (Figure 32). A similar pattern can be seen in the TNReady science data (Grades 3-8) (Figure 33) and in the Biology end of course exam data (Figure 34).

Figure 32: SES Disparities in math grades 3-8 (2010-2022)



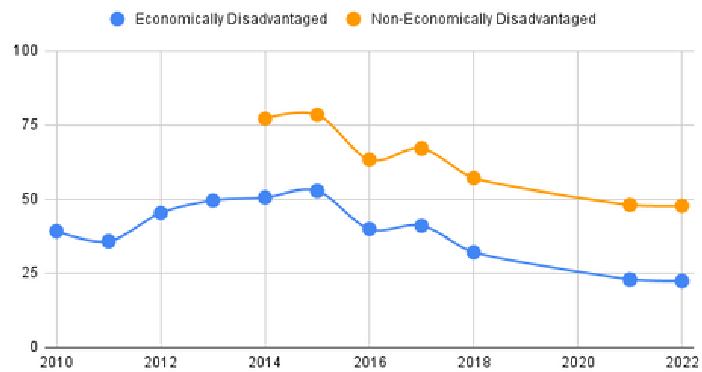
Source: Tennessee Department of Education

Figure 33: SES Disparities in science grades 3-8 (2010-2022)



Source: Tennessee Department of Education

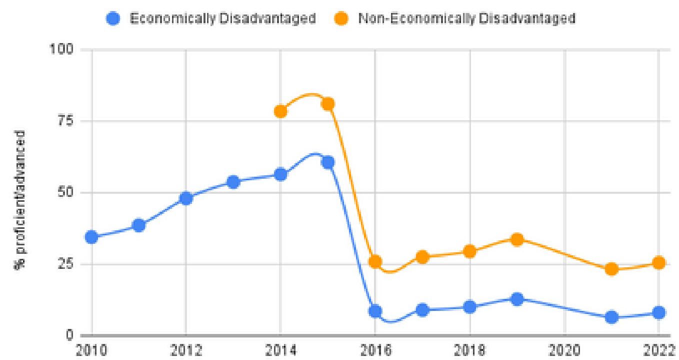
Figure 33: SES Disparities in science grades 3-8 (2010-2022)



Source: Tennessee Department of Education

Algebra end of course exam data in Tennessee shows an even more troubling reality. Since new math standards were adopted in Tennessee, students identified as economically disadvantaged have only twice achieved proficiency rates greater than double digits, peaking at 1 in 8 students proficient in Algebra. Among students not identified as economically disadvantaged, the proficiency rate in Algebra hovers near 1 in 4 students in 2022, and among students who are classified that way, the proficiency rate is 1 in 12 (Figure 35). This extremely low proficiency rate carries implications for future STEM workforce readiness, specifically.

Figure 35: SES Disparities inAlgebra (2010-2022)

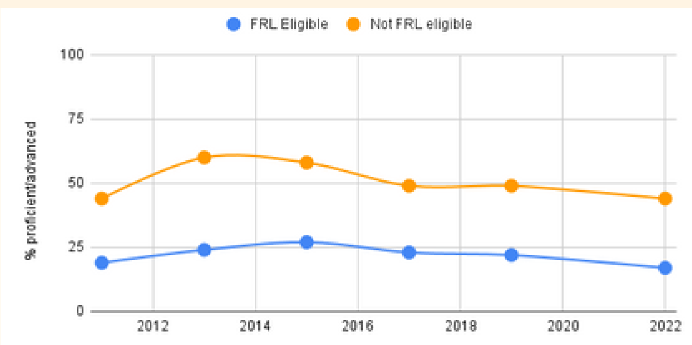


Source: Tennessee Department of Education

SOCIOECONOMIC STATUS: NAEP DATA

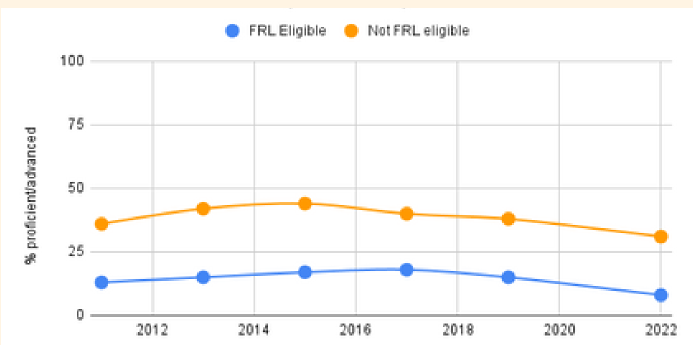
NAEP math and science data shows similar disparities correlating with socioeconomic status. Slight gains in proficiency 2011-2013 recognized among more affluent students are not matched by similar gains among those not eligible for free or reduced price lunch, and those same students have been attaining proficiency in math (both 4th and 8th grades) at lower rates every year since 2017, never showing rates higher than 1 in 4 students. (Figure 36; Figure 37). Similarly, the NAEP science assessment, last given in Tennessee in 2015 revealed a 27 percentage point lower proficiency rate among FRL eligible students in 4th grade (Figure 38) and 28 percentage points lower in 8th grade (Figure 39).

Figure 36: SES Disparities in NAEP 4th Grade Math (2010-2022)



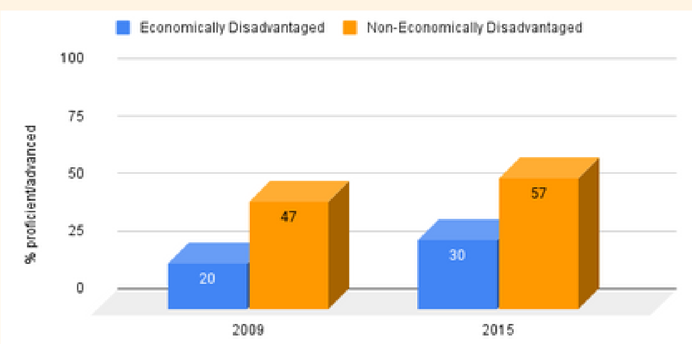
Source: NAEP

Figure 37: SES Disparities in NAEP 8th Grade Math (2010-2022)



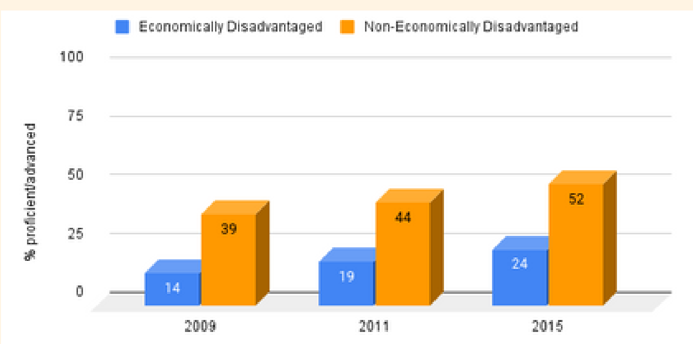
Source: NAEP

Figure 38: SES Disparities in NAEP 4th Grade Science (2009-2015)



Source: NAEP

Figure 39: SES Disparities in NAEP 8th Grade Science (2009-2015)

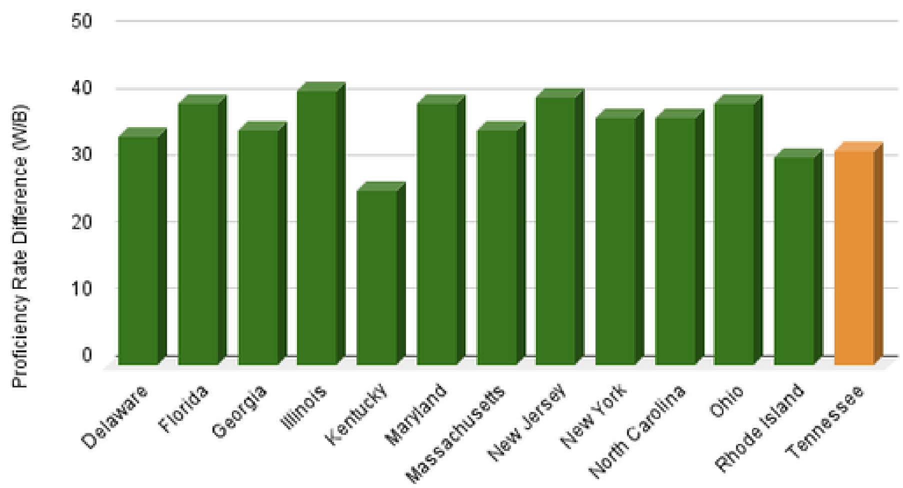


Source: NAEP

RACE TO THE TOP STATE COMPARISONS: RACE AND GENDER

Tennessee's wide disparities in math and science proficiency across race and income indicators lie in the middle of the pack across Race to the Top states. For example, in 2015's 4th grade NAEP science assessment, only Kentucky had a lower disparity in proficiency rates between its White and Black students, although some of the states with higher gaps also posted higher proficiency rates overall. (Figure 40)

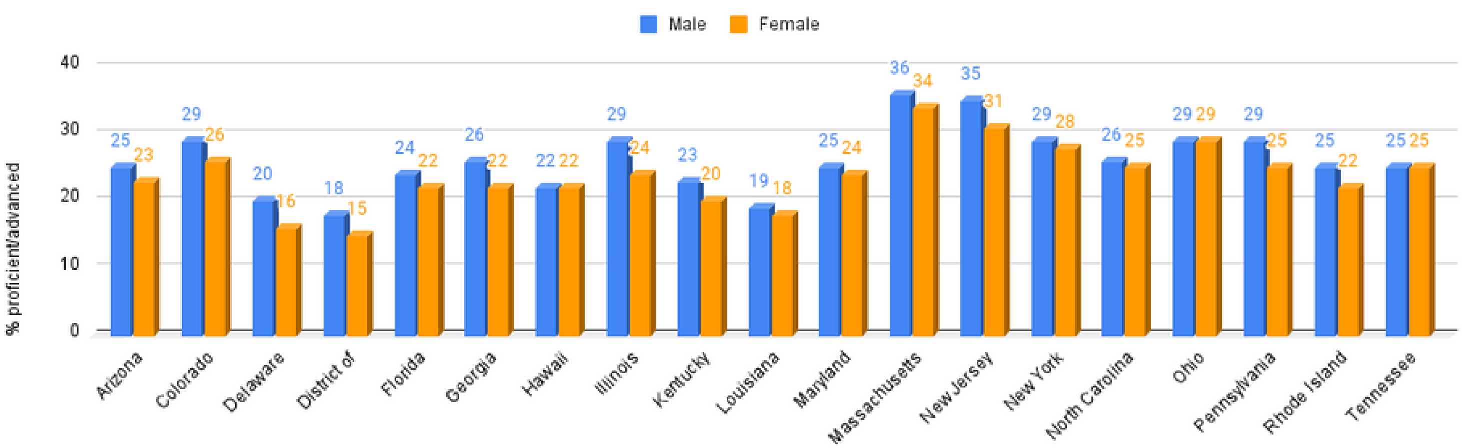
Figure 40: White-Black score gaps 4th grade science (NAEP 2015)



Source: NAEP

Interestingly, Tennessee's male-female gender gap seen in 8th grade NAEP math proficiency rates disappeared completely in 2022, and the only other comparison states to achieve that parity were Ohio and Hawaii. Every other comparison state showed male proficiency rates higher than those of female 8th grade students. (Figure 41)

Figure 41: Male-Female score gaps 8th grade math (NAEP 2022)



Source: NAEP

Persistent Inequities: Associated Findings

- Substantial inequities persist across race and socioeconomic indicators. Despite articulating aggressive commitments in its Race to the Top application to "significantly increase the number of students who make the successful transition to careers in STEM fields and promote the participation of women, minority, and economically disadvantaged students to equal participation by white males (RMC Research Corporation, 2011), wide disparities in student outcomes persist in Tennessee. The degree to which these commitments translated into plans for addressing inequitable preparation in STEM fields for students of color and students experiencing poverty is uncertain, and we will investigate that question more fully in our Phase II report. However, these data show consistently that race and income are strongly associated with K-12 preparation in math and science, thereby leaving countless students outside of the STEM pathways that the state seeks to meet growing demand in STEM careers. In algebra, an important gateway to both future STEM careers and even high school graduation, only 1 in 4 of Tennessee's students identifying as White achieved proficiency in 2022 after a small bounce back to 2016 level following pandemic declines. Yet, students of color faced even greater barriers and only 13% of Hispanic students and 7% of students identifying as Black received the preparation they needed to achieve proficiency in Algebra I that same year.

- Further investigation and understanding of causes of continuing disparities in K12 outcomes across race and income classifications is needed. Much has been learned about previous approaches to equity in education since 2010, and educational research can help to uncover new understanding and associated approaches. While K12 outcomes serve as strong predictors of future STEM careers, they are only predictors and broader explanation is required before more effective recommendations can be developed. This will be a focus of the Phase II report in this series.

- Deeper understanding of the role of Algebra as gatekeeper to high school graduation, postsecondary matriculation, persistence, and completion, and associated interests and identities should be centered in any recommendations for reducing disparities. Significant disparities in Tennessee's high school Algebra proficiency rates by race and income carry their own associated identity issues and suggest improvements in educator preparation, instructional methods, as well as early grades identity formation in mathematics, continuing representation in mathematics that are culturally inclusive and responsive, as well as access to high quality instructional materials and questions about the proper sequencing of mathematics curricula, access to advanced courses, educators with greater content knowledge, and more. A deeper investigation of these and other factors will also inform the Phase II report in this series.

- More investigation of the experiences of females in STEM courses and careers is needed to uncover more explanation of their relatively positive K12 achievement levels in math and science courses as compared to their persistent underrepresentation in STEM career fields. Research that identifies K12 academic course taking and performance levels as strong predictors of postsecondary STEM majors and pursuit of STEM careers fall short of explaining this gender disparity and call for further investigation and understanding.

- Disparity data in K12 math, science, and technology and engineering literacy show that ambitious goals alone, like those in Tennessee's Race to the Top Application, in the absence of sustained, specific, and culturally responsive interventions have done little to move the results. It is good, but not enough, to aspire to see STEM participation and success rates among students of color and those experiencing poverty match those of white males. That articulated aspiration from 2010 (Tennessee's Race to the Top application) has plainly not shown the desired outcomes, and where the achievement of proficiency is more closely matched across genders, pursuit of subsequent STEM careers has not followed. Achieving equity in STEM education and STEM careers requires more than hope.

HIGHLIGHTS

Substantial inequities persist in STEM outcomes across race and socioeconomic indicators

More investigation and study of the structural causes of inequities if continuing disparities critical

Need deeper understanding of the role of Algebra in the STEM pathway, especially for students left behind

Need to develop stronger pathways for women and girls in STEM majors and STEM careers

Tailored action needs to accompany ambitious equity goals in Tennessee

Programs Established through Race to the Top

The central focus of the Race to the Top competition included four core areas (RMC Research Corporation, 2011):

- Standards and assessments
- Data systems
- Effective teachers
- School turnaround

The second of 6 competitive priorities asked applicant states to develop an emphasis on science, technology, engineering, and mathematics (STEM). While this priority only accounted for 3% of the available points in the application review, applications with STEM improvement plans were preferred over comparable applications without them (Offices of Research and Education Accountability, 2010, p. 12). Interestingly, the press release announcement of Tennessee's successful application that was published on the Tennessee's Department of Education website did not include mention of the STEM plan (Tennessee Wins Race to the Top Grant, 2010).

In order to meet the STEM priority, Tennessee was required to address three areas (RMC Research Corporation, 2011, p. 2):

- Increasing rigor in STEM courses of study.
- Preparing and assisting teachers to integrate STEM across grades and disciplines offering effective and relevant instruction and applied learning opportunities for students through cooperation with industry experts, museums, universities, research centers, or other STEM-capable community partners.
- Addressing the needs of under-represented groups and of women and girls in the STEM areas.

Tennessee's application included both reforms already underway in 2010 as well as those top-level reforms proposed within the 4 core (not STEM-specific) areas of the application, highlighting the impact of rigorous standards, strong data systems, policies promoting effective teachers, and intentional school turnaround work on STEM education at the same time.

So, for example, Tennessee's approach to increasing rigor in STEM courses of study capitalized on the Tennessee Diploma Project implemented in 2009 which promoted more rigorous standards that would improve Tennessee's expectations compared with those in other states. The Tennessee Diploma Project also led the state to set Tennessee's graduation requirements to 22 credits including 4 in mathematics and 3 in science. Tennessee's graduation requirements also included a 3 credit elective focus that would help to concentrate advanced course taking and encourage pursuit of career and technical education (CTE) concentrations, many of which are aligned with STEM careers (RMC Research Corporation, 2011; Graduation Requirements, n.d.).

Additionally, Tennessee committed at the time to adoption of the Common Core State Standards (CCSS) in mathematics and to enter into the Partnership for Assessment for Readiness for College and Career (PARCC) consortium to develop assessments aligned with the Common Core State Standards (CCSS) (RMC Research Corporation, 2011).

STEM-specific proposals to increase rigor in Tennessee's application included the launch of the **Tennessee STEM Innovation Network (TSIN)**, a partnership with Battelle for Kids, the University of Tennessee, and the TN Department of Education to "establish a statewide network of programs and schools designed to promote and expand the teaching and learning of science, technology, engineering, and math" (Offices of Research and Education Accountability, 2010, p. 11). The intended outcomes of the TSIN spoke to all of the competitive priority's focus areas (rigor, teachers, and underrepresented groups) including increasing the number of students graduating under the new Tennessee Diploma Project requirements, increasing the number of students pursuing postsecondary degrees in STEM fields and transitioning to STEM careers. The TSIN was intended to serve as a "self-sustaining" network of collaboratively developed and maintained resources to support instruction, assessment, content knowledge, and connections to STEM career fields as well as innovations in STEM education to continuously support improvements in STEM education. Finally, the goal of the TSIN was to motivate more participation in STEM fields among "female, minority and economically disadvantaged students" so that their participation rates would match those of white males in STEM fields and careers (Offices of Research and Education Accountability, 2010, p. 11).

Programs Established through Race to the Top (cont'd)

Additionally, Tennessee's application proposed expanding its Virtual School to improve high school completion and the potential for college dual enrollment as well as extending the reach and availability of advanced STEM courses to students whose school could not offer these courses whether in urban or rural areas of the state (RMC Research Corporation, 2011). To support this work and also test innovations and demonstrate successful efforts, Tennessee also highlighted "two STEM platform schools and plans to add three additional STEM schools or leadership development programs" (RMC Research Corporation, 2011).

In addition to these overlapping efforts, Tennessee's application also included specific work to be done in advancing teacher effectiveness including both pre-service preparation and ongoing professional development, primarily promoted by the TSIN, including development of regional STEM hubs, centers for professional development in math and science education, leadership development programs, an annual STEM education conference and other workshops, and a website for continued professional development. In preservice preparation, the application highlighted new and continuing teacher residencies with a STEM discipline focus in Chattanooga and Knoxville that were at the time supported by the University of Tennessee and the Chattanooga Public Education Foundation (TEACH/Here and UTeach) (RMC Research Corporation, 2011).

Finally, addressing the requirement to prepare more students, including those from underrepresented groups, Tennessee's application was bold in articulating a desired outcome where all students would graduate, matriculate to and through STEM postsecondary majors, and enter STEM career fields at rates equal to those among white male students (RMC Research Corporation, 2011). Most of the theory of improvement toward realization of this goal centered on more rigorous standards and more effective teaching supported through the other proposed activities and centered in the work of the Tennessee STEM Education Network (TSIN). Few, if any, race, income, or gender-specific interventions were articulated.

tsin Tennessee STEM Innovation Network

Recent Programs Addressing STEM

In the 13 years since Tennessee was awarded its $500 million Race to the Top grant, the state has also invested in several new efforts to promote and support STEM education. These initiatives span from focusing on curriculum to STEM course access.

In 2015, the Tennessee State Board of Education began the process to review and revise the state's academic standards for grades K-12 across all major subject areas. This process engaged K-12 educators and higher education faculty and collected public feedback from Tennesseans. As a result, the state released revised standards for math and science instruction in 2016. The new math standards were implemented in classrooms across Tennessee in the 2017-18 school year, and the new science standards were implemented in the 2018-19 school year (Tennessee State Board of Education, 2023). A key focus in both sets of standards were higher order, conceptual thinking skills. In math this includes a set of standards for mathematical practice and conceptual skills taught throughout all grades.

Figure 45: Features of Revised Tennessee Academic Standards for Math (Tennessee State Board of Education, 2022)

Concepts and Skills
• Counting and Cardinality • Operations and Algebraic Thinking • Number and Operations in Base Ten • Measurement and Data • Geometry

Standards for Mathematical Practice
1. Make sense of problems and persevere in solving them. 2. Reason abstractly and quantitatively. 3. Construct viable arguments and critique the reasoning of others. 4. Model with mathematics. 5. Use appropriate tools strategically. 6. Attend to precision. 7. Look for and make use of structure. 8. Look for and express regularity in repeated reasoning.

The revised science standards also feature an enhanced focus on conceptual learning with a set of crosscutting concepts that are essential for highlighting the interdependent connections amongst sciences (Tennessee State Board of Education, 2017):

- Pattern observation and explanation
- Cause and effect relationships that can be explained through a mechanism
- Scale, proportion, and quantity that integrate measurement and precision of language
- Systems and system models with defined boundaries that can be investigated and characterized by the next three concepts
- Energy and matter conservation through transformations that flow or cycle into, out of, or within a system
- Structure and function of systems and their parts
- Stability and change of systems

The revisions also include a set of science and engineering practices with the goal to "allow students to discover how scientific knowledge is produced and how engineering solutions are developed" (Tennessee State Board of Education, 2017):

- Asking questions (for science) and defining problems (for engineering) to determine what is known, what has yet to be satisfactorily explained, and what problems need to be solved.
- Developing and using models to develop explanations for phenomena, to go beyond the observable and make predictions or to test designs.
- Planning and carrying out controlled investigations to collect data that is used to test existing theories and explanations, revise and develop new theories and explanations, or assess the effectiveness, efficiency, and durability of designs under various conditions.
- Analyzing and interpreting data with appropriate data presentation (graph, table, statistics, etc.), identifying sources of error and the degree of certainty. Data analysis is used to derive meaning or evaluate solutions.
- Using mathematics and computational thinking as tools to represent variables and their relationships in models, simulations, and data analysis in order to make and test predictions.
- Constructing explanations and designing solutions to explain phenomena or solve problems.
- Engaging in argument from evidence to identify strengths and weaknesses in a line of reasoning, to identify best explanations, to resolve problems, and to identify best solutions.
- Obtaining, evaluating, and communicating information from scientific texts in order to derive meaning, evaluate validity, and integrate information

Recent Programs Addressing STEM (cont'd)

These changes in standards also drove changes to textbooks and curricular materials as state policy requires approved curricular materials to align to the academic standards.

In 2014, the Tennessee Department of Education convened a STEM Leadership Council composed of educators, state government, higher education, and nonprofit organization leaders. This council with the support of the Tennessee Department of Education developed a STEM Strategic Plan. This plan outlined four priority areas, reflective of the state's revised math and science standards, for STEM education (Tennessee Department of Education, 2018).

Figure 44: Focus Areas of Tennessee STEM Strategic Plan

It is unclear the specific progress made to date on each of these priority areas and including the work of the STEM Leadership Council.

The most recent state-level STEM programs and initiatives have been focused on increasing STEM opportunities to prepare students for workforce trends and openings. In early 2019, Governor Bill Lee announced the creation of a new grant program, the Governor's Investment in Vocational Education (GIVE), which is designed to expand access to vocational and technical training. The grants are designed to forge partnerships between a local Tennessee College of Applied Technology (TCAT) and industry partners, and the K-12 school district (*Gov. Bill Lee Announces The Governor's Investment in Vocational Education (GIVE) Initiative,* n.d.). Across two rounds of funding, one in late 2019 and another in 2021, more than $50 million has been awarded through this grant program. Several STEM-focused grants have won significant awards. Winning grants have included efforts to advance health sciences preparation, improve IT skills, and accelerate advanced manufacturing and robotics programs (*Gov. Lee Awards GIVE Grants to Fuel Rural Workforce Development,* 2021).

Additionally, In 2019, Governor Lee announced a bold initiative, the Future Workforce Initiative, "to put Tennessee in the top 25 states for creating technology jobs through launching new Career and Technical Education (CTE), Computer Science (CS), and STEM-focused programs in public schools" by 2022 (*Governor Lee's Future Workforce Initiative Impacts Nearly 400,000 Tennessee Students & 2,000+ Educators,* 2021). This initiative partnered with the Tennessee STEM Innovation Network (TSIN) and focused on three primary strategies:

1. Launching new CTE programs focused in STEM fields with **100 new middle school programs and tripling the number of STEM-designated public schools by 2022.**

2. **Growing the number of teachers qualified to teach work-based learning and advanced computer science courses** through STEM teacher training and implementation of K-8 computer science standards.

3. Expanding postsecondary STEM opportunities in high school through **increased access to dual credit, AP courses and dual-enrollment** (Gov. Bill Lee Announces The Future Workforce Initiative, n.d.).

Recent Programs Addressing STEM (cont'd)

In 2020-21, this initiative impacted 393,483 students and 2,271 teachers reaching 86% of Tennessee counties (*Governor Lee's Future Workforce Initiative Impacts Nearly 400,000 Tennessee Students & 2,000+ Educators*, 2021). Entering 2023, STEM and STE(A)M designations were awarded to 26 new schools, bringing the total to 114 schools statewide (*TDOE, TSIN Announce 26 Tennessee Schools Receive STEM/STEAM Designation*, 2023), and 175 educators were trained in the STEM CTE Program of Study, thereby further increasing access to STEM instruction across the state (*TDOE, TSIN Announce 27 Tennessee Schools Receive STEM/STEAM Designations*, n.d.).

As part of the Governor's Future Workforce Initiative, computer science was also the focus of Public Chapter 454 which charged the Tennessee Department of Education to develop a state plan for computer science (Tennessee Department of Education, 2020b). This legislation and the resulting strategic plan outlined several strategic goals:

- Ensure public high school students have access to at least one (1) computer science course;
- Integrate computer science into elementary education;
- Allow computer science course completion to count as a core admission requirement at state institutions of higher education;
- Develop educator preparation program standards and requirements for computer science;
- Increase the number of underrepresented student groups earning college credit in computer science while still in high school; and
- Ensure opportunities for educators who teach computer science to earn the computer science endorsement approved by the state board of education.

More recently, computer science was further promoted in Chapter 979 of the Public Acts of 2022. This recent legislation requires that all elementary, middle, and high school students have access to computer science coursework. It also provides a no-cost pathway for teachers to gain a computer science teaching endorsement (Tennessee Department of Education, 2022).

This will ensure that at least one computer science course will be required in middle school and another in high school. The impact on this legislation remains to be seen, as the new computer science standards will not be passed and available to schools until the 2023-24 school year, and the law will not be fully implemented until the 2024-25 school year.

CONCLUSIONS AND NEXT STEPS

Data in Tennessee highlights a great demand for a prepared and skilled STEM workforce, and while Tennessee has seen indications of progress in STEM outcomes at the state level since 2009, these results have also been characterized by frequent disruptions in the data resulting from changes in standards, testing issues, and the COVID-19 pandemic. This makes it challenging to develop a comprehensive and holistic view of student performance. Incorporating national assessment data, provides more insight and shows that Tennessee students generally improved more rapidly than students nationally and in other Race to the Top states; however, overall proficiency declined during the pandemic.

An examination of the programmatic efforts to improve STEM education highlight the efforts that began as part of the Race to the Top application to strengthen academic standards and launch the Tennessee STEM Innovation Network (TSIN), among several other initiatives. This work continued after the Race to the Top period, with continued work to improve academic standards and the development of several workforce aligned programs that provided funding to increase STEM programming, like computer science instruction.

In the second phase of this report, we will explore the lasting impacts of some of the programmatic initiatives, highlight successful national efforts to improve STEM education, and offer recommendations of ways that Tennessee can continue to promote STEM education and increase student success.

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