Shaping Tennessee's Future

STEM

Workforce Challenges and Opportunities

MIDDLE TENNESSEE STATE UNIVERSITY

JONES COLLEGE OF BUSINESS

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Mind2Marketplace

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Mind2Marketplace (M2M) is an organization dedicated to bringing the brightest and best ideas in middle Tennessee to reality. M2M strategically links people and organizations to bring innovation and technology to the marketplace. In addition to working with our partners to produce studies like the 2015 STEM Dynamics Report, M2M also hosts events such as touring of the Nissan Battery Plant where discussions centered around the federal initiative- Investing in Manufacturing Communities Partnership (IMCP); session on Unmanned Aerial Systems held at the Smyrna/ Rutherford County Airport –discussions about drone emergence and its legal, research, development and entrepreneurial considerations; and a review of Entrepreneurial Spaces held at the Rutherford County Chamber of Commerce.

For over 30 years, the Tennessee Small Business Development Center (TSBDC) network, headquartered at Middle Tennessee State University, has been empowering small business owners, entrepreneurs, and individuals with a business idea to innovate new products and services that compete in the global marketplace. The TSBDC provides unbiased business advice to those seeking answers to business related questions, or looking for training courses to improve their workforce. The TSBDC is a network of certified professional business counselors conveniently located with 20 locations statewide.

Table of Contents

Shaping Tennessee's Future:

STEM Workforce Challenges and Opportunities

Executive Summary

The Business and Economic Research Center (BERC), at Middle Tennessee State University, under a partnership with Mind2Marketplace assessed critical challenges and opportunities in the STEM (science, technology, engineering, mathematics) fields across Tennessee. A survey of businesses, mayors, local economic development officials, and school principals suggests that Tennessee faces significant challenges in the STEM workforce supply, pipeline, and infrastructure.

Key Findings:

Employment and Skill Gap

- As of 2013, the size of the STEM workforce in Tennessee is around 324,328.
- The STEM workforce in Tennessee is characterized as an oversupply of a low skilled STEM workforce relative to the U.S. average.
- To catch up with the rest of the U.S. in the relative share of the STEM workforce, 36,000 new STEM jobs are needed in Tennessee.
  - Creating these new jobs and addressing skill issues would generate an economic impact of nearly $4.5 billion.

STEM Workforce Challenges

- Challenges associated with the factors affecting the supply of STEM workforce include:
  - Perceived lack of rigor in Tennessee's K12 education system
  - Lack of knowledge about programs
  - Lack of interest and ability
  - Lack of emphasis on the necessity of difficult subjects

- Challenges associated with the STEM pipeline include:

  - More than 88 percent of community stakeholders indicated that the Tennessee education system does not produce enough quality/competitive individuals.

    - About 78 percent of community stakeholders did not think that students are graduating with the proper skills for STEM-related jobs.
    - About 73 percent of community stakeholders argued that the workforce in Tennessee is not going to meet the demands of advanced technology.
    - Community stakeholders rank math proficiency as the number-one, and connecting education with employment as the number-two critical challenge for Tennessee.

- Challenges associated with the government and infrastructure include:
    - Community stakeholders indicated that the role of government in promoting the STEM workforce should be in the areas of funding, promotion, incentives, and awareness.
    - Among the nearly 50 recommendations, making connections between educational institutions and workforce needs tops the rankings as potential ways to engage business, industry, and other community partners in advancing STEM.
    - About 82 percent of community stakeholders indicated that there is potential for aligning and coordinating STEM resources across the state.

- Challenges to businesses include:
    - Businesses suggested that technology advancement affect their businesses in many ways: efficiency, continuous improvement, new opportunities, and product development, among others.
    - Inability to fill STEM-related jobs creates significant problems for businesses, and their growth will be impacted.
    - Businesses indicated that the shortage of a local STEM workforce will increase their costs through training programs, non-local recruiting, and relocation.
    - Businesses face the following challenges in recruiting a STEM workforce: skilled labor force, financial challenges, location challenges, and STEM awareness.

STEM Workforce Demand and Supply Gap

- Annual average STEM degree production is estimated at around 11,195.
- Annual average demand (new and replacement) for STEM workers is estimated at 18,897.
- According to supply-and-demand estimates as well as replacement numbers, the supply-to-demand ratio is estimated at around 0.59, suggesting that 41 percent of demand will be unmet locally.

Conclusion

Addressing the STEM workforce challenge is critically important for Tennessee for two major reasons:

- Building the capacity for innovation and creativity: A STEM workforce is highly educated relative to all other occupations in an economy. For Tennessee, the advanced manufacturing and healthcare industries have become major drivers of economic growth. To build sustainable economic growth, Tennessee should build the capacity of its workforce.
- Fueling the economy with additional household income: Addressing the low-skill problem and moving Tennessee's STEM concentration to the national level alone would create an economic impact of nearly $4.5 billion and create an additional 16,000 new jobs in the economy.

Chapter 1

Understanding STEM Workforce Dynamics in Tennessee

What is the STEM workforce? What role does it play in an economy? What are its major characteristics? The key to understanding STEM (science, technology, engineering, and math) workforce dynamics lies in the answers to these three basic questions. A review of several studies shows there is no consensus on what the STEM workforce should include.[1]

In terms of the meaning of the STEM workforce, two general definitions emerge:

1. Individuals holding a STEM occupation or
2. Individuals holding a STEM degree.

Although a hybrid approach combining both definitions may provide a better understanding of the STEM workforce, the former is easily quantifiable for research purposes.

Which occupations should be considered STEM occupations? The following options are widely used by individual researchers and agencies:

1. STEM occupations,
2. STEM-related occupations, and
3. (Sometimes) social science occupations.

This report uses an occupational definition of the STEM workforce. Consistent with the definition of the U.S. Census Bureau, this approach includes both STEM and STEM-related occupations, including several social science occupations. A total of 98 occupations (63 STEM and 35 STEM-related) are included in the analysis.

Why is the STEM and STEM-related workforce important to an economy?

Since the early 1990s, fast-paced economic transformations within the United States and across the globe have dramatically reduced industry and product life cycles. This in turn has created tremendous challenges and opportunities. For example, Tennessee when it lost its traditional manufacturing base throughout the 1990s and 2000s. Only during the past

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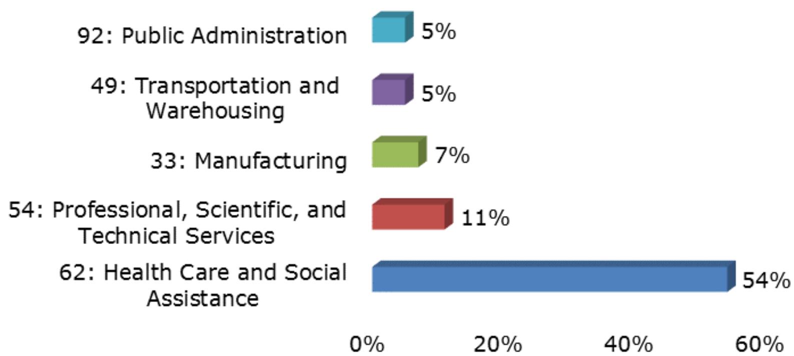
[1] See multiple reports and crosswalks developed by the National Science Foundation (www.nsf.gov), U.S. Census Bureau (www.census.gov), and Bureau of Labor Statistics (www.bls.gov).

decade has the state started rebuilding its manufacturing base, not in traditional sectors such as textiles and furniture, but in the advanced manufacturing and automotive sectors. In this transformed manufacturing space, the STEM workforce plays a critical role as a driver of innovation and competitiveness.

Distribution of STEM Jobs by Industry in Tennessee (2014) (Ages 25+)



Source: Census Bureau

In Tennessee, the main sectors driving the economy are advanced manufacturing; automotive; professional and business services; health care; transportation; and logistics. These are the major industries employing a substantial percentage of the STEM and STEM-related workforce. Because of the state's heavy reliance on these industries for job growth and economic prosperity, it is important to understand STEM workforce dynamics in Tennessee.

What are some characteristics of STEM occupations? One important aspect of the STEM workforce is that individuals holding these occupations are highly educated. The percent of STEM bachelor's degree-holders is twice as many as percent of bachelor's degree holders in all other occupations in Tennessee. This has two implications for the state's economy:

(1) Wages and salaries are closely related to educational attainment levels. The higher the educational attainment level of the workforce, the higher the purchasing power of individuals in the economy.

(2) A highly educated workforce is a major source of innovation and entrepreneurial activity.

However, in terms of STEM workforce characteristics, two issues require further elaboration:

(1) Not all workers in STEM occupations have a bachelor's degree or above. Many "technical" occupations that play a critical role in highly competitive industries require only specific training after high school.

(2) Not all individuals in STEM occupations have STEM degrees. As will be highlighted in the following chapters, the STEM survey indicates that about 65 percent of STEM workers in Tennessee have STEM degrees. The remaining 35 percent have degrees in other fields or no degree beyond high school. This means either companies are facing difficulty hiring employees with the right credentials, or STEM degree holders are not seeking opportunities in their areas of expertise.

Understanding and analyzing the STEM workforce within a state context requires an understanding of supply and demand dynamics and pipeline issues.[2] The Business and Economic Research Center (BERC) invited businesses, mayors, school administrators, and economic development professionals across Tennessee to assess STEM workforce challenges and opportunities in shaping Tennessee's future.

The rest of the report is organized as follows. Chapter 2 looks at STEM workforce indicators from a comparative perspective. Chapters 3-5 address the outlook of community stakeholders on STEM workforce supply, pipeline issues, infrastructure, and government as related to the STEM workforce. Chapter 6 focuses on current demand conditions, future expectations and strategies, and supply-and-demand conditions expected in the next 10 years. Chapter 7 presents selected occupational dynamics. Chapter 8 concludes with an index of STEM concentrations across Tennessee.

[2] The concept of "STEM workforce" will be used throughout the report to include both STEM and STEM-related occupations.

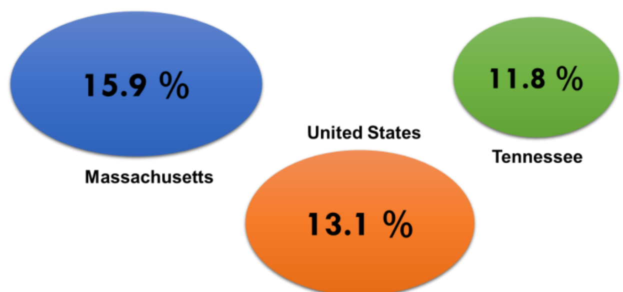
Chapter 2

STEM Workforce by the Numbers

How many STEM and STEM-related jobs does Tennessee have? What are their characteristics? According to BERC estimates using American Community Survey data (2011–2013), Tennessee has 324,328 STEM and STEM-related jobs. What does this number mean for Tennessee? It means that in 2013, nearly 12 percent of all jobs were STEM and STEM-related occupations. The size of Tennessee's STEM workforce is smaller compared with the national average and well behind some of the states such as Massachusetts. In the same year, according to BERC estimates, 13.1 percent of all jobs in the U.S. and 15.9 percent in Massachusetts were in STEM and STEM-related occupations. Increasing Tennessee's STEM workforce to the U.S. average would mean adding 36,000 STEM and STEM-related jobs to the economy.

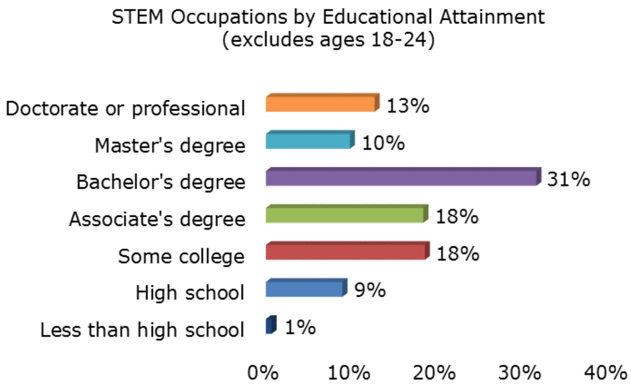
STEM Occupations
124,752 jobs

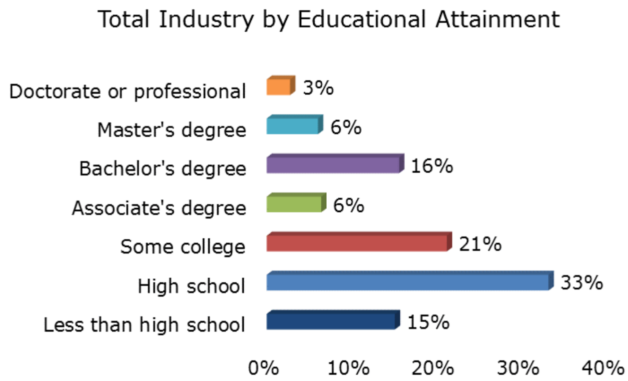
STEM-Related Occupations
199,576 jobs



Sources: BERC, BLS, and Census Bureau

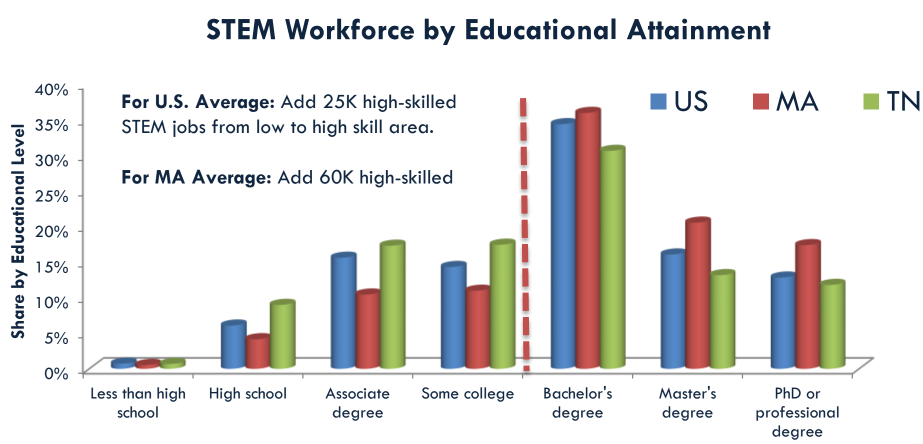
What is the educational attainment level of the STEM workforce compared with all industries? Overall, the STEM workforce has a higher educational attainment level than the average in Tennessee. The share of graduate degree-holders in all occupations in Tennessee is nine percent, significantly lower than that of STEM occupations (23%). At the bachelor's degree level, the difference is equally striking: 31 percent of STEM employees have a bachelor's degree, compared with 16 percent of employees in all industries combined. A similar pattern is visible in the category of "some college or associate's degree": 36 percent of STEM employees have either some college or an associate's degree, compared with 27 percent of employees in all industries. The trend continues for the last two categories: 10 percent of STEM employees have only a high school education or less, compared with nearly half (48 percent) of all workers in Tennessee.





Source: Census Bureau

The STEM workforce in Tennessee also can be characterized as having an oversupply of low-skilled workers. In all areas beyond some college, there is a non-trivial gap between Tennessee and the United States or the state of Massachusetts. The gap suggests that to catch up with the U.S. average, Tennessee should shift 25,000 low-skilled jobs to high-skilled jobs either through lifelong learning or replacement of retiring workers. This number increases to 60,000 jobs in order for Tennessee to reach the education attainment level of the STEM workforce in Massachusetts.



Sources: BERC and American Community Survey (ACS) 2012 through IPUMS.org

For example: 22.11 percent of computer-network architects in Tennessee have a bachelor’s degree or above, compared to 55.41 percent of individuals in this occupation in the U.S. (a gap of 33.31 percentage points.) For miscellaneous social scientists and related workers, the educational attainment gap is 31 percent.

SOC	Occupations	U.S. Bachelor's & Above	TN Bachelor's and Above	Skill GAP (Percentage Point)
172121	Marine engineers and naval architects	68.69%	34.18%	34.51%
151143	Computer network architects	55.41%	22.11%	33.31%
1930XX	Miscellaneous social scientists and related workers	88.64%	57.64%	31.00%
194031	Chemical technicians	39.53%	17.49%	22.04%
1721XX	Enginers, all other	78.57%	56.75%	21.83%
15113X	Software developers, applications and systems software	84.01%	70.19%	13.82%
1910XX	Life scientists, all other	98.52%	85.72%	12.80%
292050	Health practitioner support technologists and technicians	19.17%	6.56%	12.60%
172110	Industrial engineers, including health and safety	72.90%	60.67%	12.23%
172070	Electrical and electronics engineers	77.82%	65.65%	12.18%
191020	Biological scientists	95.88%	84.14%	11.74%
292071	Medical records and health information technicians	17.55%	6.46%	11.10%

Sources: BERC and American Community Survey (ACS) 2012 through IPUMS.org

Such a large gap across several STEM occupations may affect long-term Tennessee's long-term competitiveness unless new generations make up the difference. Are new generations helping to close the educational attainment gap in STEM occupations in Tennessee? A look at the educational attainment level by age cohort in STEM occupations suggests intergenerational differences are closing the educational attainment gap between Tennessee and the U.S. However, educational attainment gaps by age cohort are larger than for Tennessee as a whole, which suggests that the educational attainment level of the Tennessee STEM workforce may not catch up with the nation in the short run. The next section summarizes further differences between Tennessee and selected states from a comparative perspective.

US				MA				TN			
Age	<College	College+	**GAP**	Age	<College	College+	**GAP**	Age	<College	College+	**GAP**
25-34	33.86%	66.14%	**32.27%**	25-34	20.19%	79.81%	**59.62%**	25-34	41.18%	58.82%	**17.64%**
35-44	35.05%	64.95%	**29.90%**	35-44	23.04%	76.96%	**53.92%**	35-44	43.43%	56.57%	**13.13%**
45-54	38.80%	61.20%	**22.40%**	45-54	27.73%	72.27%	**44.55%**	45-54	44.20%	55.80%	**11.60%**
55-64	40.19%	59.81%	**19.63%**	55-64	35.20%	64.80%	**29.60%**	55-64	29.19%	50.81%	**16.20%**
65-74	36.58%	63.42%	**26.84%**	65-74	29.09%	70.91%	**41.81%**	65-74	45.83%	54.17%	**83.30%**
75-84	34.93%	65.07%	**30.15%**	75-84	30.18%	69.82%	**39.64%**	75-84	53.26%	46.74%	**-6.51%**
85+	34.80%	65.20%	**30.40%**	85+	23.37%	76.63%	**53.27%**	85+	41.22%	58.78%	**17.56%**

Keys:
Age: age cohort
<College: Less than college education
College+: Bachelor's and above
Gap: "College+" minus "<College"
Sources: BERC and American Community Survey (ACS) 2012 through IPUMS.org

How does Tennessee compare with other selected states on STEM-related indicators? To present a balanced perspective, this report includes a set of STEM-related indicators that allow for state-by-state comparison. A total of nine states are compared with each other in the areas of STEM pipeline, higher-education dynamics, workforce, R&D and innovation, high-tech, venture capital, and entrepreneurship.

Pipeline. Among nine states, Tennessee and Mississippi have the lowest expenditure per-student for elementary and secondary public schools spending only $8,117 and $8,104, respectively. Massachusetts and Virginia have the highest with $14,699 and $10,594, respectively. The per-student annual spending gap between Tennessee and Massachusetts is $6,582. Tennessee is one of the states with the lowest percent of public-school students taking Advanced Placement exams (17.8 percent). The gap between Tennessee and Virginia, for example, is 24 percentage points in this category.

Pipeline	Expenditure per student for elementary and secondry public school (2010, $)	Public school students taking Advanced Placement exams (2012, %)	Eighth-Grade math proficiency (2011, %)	Eighth-Grade science proficiency (2011, %)
Tennessee	**$8,117**	**17.8**	24	31
Alabama	$8,907	22.2	**20**	**19**
Georgia	$9,432	39.7	28	30
Kentucky	$8,957	29.8	31	34
Massachusetts	**$14,699**	35.8	**51**	**44**
Mississippi	**$8,104**	**14.0**	**19**	**19**
North Carolina	$8,225	30.1	37	26
Texas	$8,788	34.4	**40**	32
Virginia	**$10,594**	**41.8**	**40**	**40**

National Science Board 2014. Science and Engineering Indicators 2014. Arlington, VA: National Science Foundation (NSB 14-01)

In the areas of math and science proficiency in eighth grade, results are mixed: While Tennessee has one of the lowest scores in math proficiency, its standing in science among nine states is average. The math proficiency gap between Tennessee and Massachusetts is 27 percentage points. *The data suggest that students in Tennessee are not succeeding in rigorous math education and Advanced Placement tests.*

Higher education. All higher-education indicators reported here suggest both challenges and opportunities for Tennessee. The main challenge will be to increase the number of graduates holding science and engineering degrees and the overall number of people with a postsecondary education. For example, the gap between Tennessee and Massachusetts in those holding a postsecondary degree is 19.2 percentage points. On a per-capita basis, Tennessee has fewer individuals with a bachelor's degree in science and engineering compared with Alabama, North Carolina, Virginia, and Massachusetts.

Higher Education (Connectors)	Bachelor's degrees in science and engineering conferred per 1,000 individuals 18-24 years old (2011)	Science and engineering degrees as a percentage of higher education degrees conferred (2011, %)	Average undergraduate charge as percent of disposable personal income (2011, %)	State expenditures on student aid per full-time undergraduate student (2011, %)	Postsecondary degree-holders among individuals 25-44 years old (2011, %)
Tennessee	$13.6	23.6	40.5	**$1,836**	34.3
Alabama	$15.4	25.0	**45.3**	**$109**	33.6
Georgia	$13.4	27.0	43.2	**$2,383**	27.7
Kentucky	$12.6	**23.0**	**48.8**	$1,323	**33.2**
Massachusetts	**$29.2**	**32.1**	41.7	$328	**53.5**
Mississippi	**$10.3**	**23.3**	40.8	**$295**	**31.8**
North Carolina	$17.3	31.4	**39.6**	$1,456	39.8
Texas	**$11.6**	27.7	**39.8**	$1,098	34.6
Virginia	**$21.6**	**32.8**	44.6	$661	**47.4**

National Science Board 2014. Science and Engineering Indicators 2014. Arlington, VA: National Science Foundation (NSB 14-01)

College education is a lot more affordable in Tennessee than in the other eight states compared here. The lottery scholarship is making it even more affordable. It is important to mention Tennessee's recent Drive to 55 effort to increase its postsecondary participation rate. It is too early to assess the effort's impact; however, it is likely that this policy may change the higher-education dynamics over the next four to five years.

Workforce (marketplace). Tennessee has an oversupply of low-skilled STEM workers. Tennessee has the third-lowest percentage of science and engineering occupations among all occupations compared with eight other states. Tennessee is performing better than Kentucky and Mississippi but lagging far behind North Carolina and Texas. In the four other categories, Tennessee is either one of the worst performers or has the lowest-third score among nine states.

Workforce	Individuals in science and engineering occupations as a percentage of all occupations (2012, %)	Engineers as a percentage of all occupations (2012, %)	Computer specialists as a percentage of all occupations (2012, %)	Technical workers as a percentage of all occupations (2012, %)	Life and physical scientists as a percentage of all occupations (2012, %)
Tennessee	3.00	0.99	**1.56**	1.13	**0.32**
Alabama	3.99	**1.60**	2.04	1.3	0.35
Georgia	3.90	**0.95**	2.65	1.28	**0.29**
Kentucky	**2.94**	0.83	1.55	0.98	**0.32**
Massachusetts	**7.16**	**1.64**	**4.17**	**1.98**	N/A
Mississippi	**2.19**	N/A	0.88	0.98	0.44
North Carolina	4.33	**0.95**	2.58	1.31	**0.60**
Texas	4.67	1.44	2.7	1.55	**0.45**
Virginia	**7.63**	1.50	**5.35**	**1.70**	0.43

National Science Board 2014. Science and Engineering Indicators 2014. Arlington, VA: National Science Foundation (NSB 14-01)

R&D and Innovation. Is Tennessee on par with other states in terms of research and development (R&D) spending and creativity? A review of four major indicators implies state agencies and businesses are not spending enough relative to eight other states. In patents per capita, Tennessee is as competitive as other reference states. Tennessee and Massachusetts still see a difference of 13.40 patents per capita in science and engineering occupations.

R&D and Innovation	R&d as a percentage of gross domestic product (2010, %)	Business-performed R&D as a percentage of private-industry output (2011, &)	State agency R&D expenditures per employed worker (2011, $)	Patents awarded per 1,000 individuals in science and engineering occupations (2012)
Tennessee	1.56	**0.62**	**1.28**	11.6
Alabama	2.16	1.27	**9.88**	**5.7**
Georgia	1.36	1.07	2.72	14.3
Kentucky	**0.93**	0.91	**10.9**	10.5
Massachusetts	**5.36**	**4.46**	**1.52**	**25.0**
Mississippi	**0.89**	**0.30**	6.2	**5.9**
North Carolina	2.05	**1.66**	7.08	**17.7**
Texas	1.59	1.30	4.12	16.9
Virginia	**2.38**	1.57	4.39	6.20

National Science Board 2014. Science and Engineering Indicators 2014. Arlington, VA: National Science Foundation (NSB 14-01)

High-tech, entrepreneurship, and venture capital. Tennessee has experienced significant growth over recent years in high-technology sectors. However, (1) the growth is uneven across Tennessee, and (2) the economic impact has yet to show up in the trend data. Both establishment and employment shares of high-tech industries in the overall economy show relatively low performance for Tennessee compared with eight other states. Likewise, in venture capital amounts and deals, there is still room to grow.

High Tech, Entrepreneurship and Venture Capital	High-Technology establishments as a percentage of all business and establishments (2010 %)	Employment in high-technology establishments as a percentage of total employment (2010, %)	Venture capital disbursed per $1,000 of gross domestic product (2012, %)	Venture capital deals as a percentage of high-technology business establishments (2010, %)	Venture captial disbursed per venture capital deal (2012, $millions)
Tennessee	6.63	9.66	0.31	0.21	**2.72**
Alabama	6.85	10.52	**0.13**	**0.03**	3.83
Georgia	9.88	13.49	0.6	**0.29**	4.94
Kentucky	**6.52**	**8.44**	**0.14**	0.24	3.43
Massachusetts	**10.12**	**15.11**	**7.74**	**2.05**	**7.46**
Mississippi	**5.91**	**7.20**	**0.1**	**0.00**	**2.50**
North Carolina	8.25	10.76	0.43	0.32	**5.32**
Texas	9.63	13.36	0.67	0.28	5.84
Virginia	**12.25**	**17.67**	**0.83**	0.22	4.59

National Science Board 2014. Science and Engineering Indicators 2014. Arlington, VA: National Science Foundation (NSB 14-01)

Key takeaways. Tennessee has several major challenges related to its STEM workforce. Some of these major challenges, as data suggests, include:

(1) addressing gaps and issues in the K12 system;

(2) increasing degree production and encouraging lifelong learning through continuing education to eliminate skill gaps in the market;

(3) hiring the right person for STEM jobs, which will pull some STEM degree-holders from other occupations into STEM occupations; and

(4) addressing critical gaps in R&D spending.

If addressed carefully, these challenges may turn into opportunities for Tennessee to increase its competitive. For example, aligning the educational attainment level of the STEM workforce in Tennessee with the United States produces two major benefits to Tennessee:

- This alignment increases the capabilities of the STEM workforce, which is key to sustainable competitive advantage.
- Addressing the skill gap and training additional individuals will generate an additional $2.328 billion in household income in wages and salaries. This will further impact the economy through multipliers, creating an additional $2.102 billion in economic activity and 16,100 new jobs. In summary, addressing these gaps will contribute $4.432 billion to the state economy and create 16,100 new jobs.

Chapter 3

Business Perceptions of STEM Dynamics in Tennessee

Who are the critical players in the STEM workforce debate? The key players are businesses, mayors, local economic development officials, and school administrators. Their insights into the opportunities and challenges of the STEM workforce have important policy implications for future economic directions in Tennessee.

To get these stakeholders' feedback, BERC designed and administered a comprehensive STEM survey in 2014. Online and mail-in surveys resulted in 210 responses across Tennessee, 65 percent directly from businesses. All nine regions of Tennessee responded, although northern middle Tennessee (27 percent), east Tennessee (17 percent), southeast Tennessee (12 percent), and southern middle Tennessee (12 percent) were represented more than other regions. In terms of industry affiliation, 45 percent of responses were from professional and business services and 33 percent from health care. The remaining 22 percent were from government, advanced manufacturing, automotive, transportation and logistics, energy technologies, and the chemical products and plastics sectors.

Some of the major characteristics of respondents:

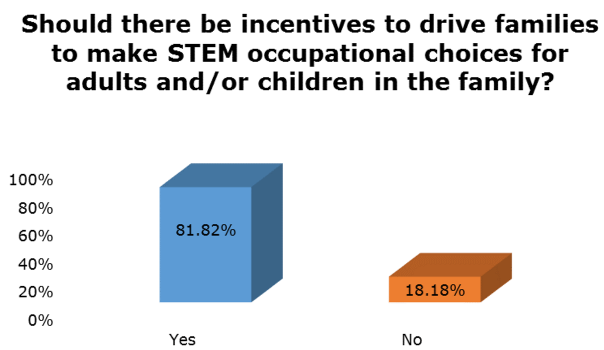
- Average employment of companies reported was 142 staff.
- Of these companies' employment, an average of 26 percent of jobs were STEM or STEM-related.
- Average spending for R&D activities of respondents was $81,000.
- An average of 19 percent of respondents indicate they participated in innovative activities such as research and development or the commercialization of patents.
- Total STEM-related R&D expenditures were nearly $10 million.
- Approximately 16 percent of respondents participated in the import and export of goods and services.

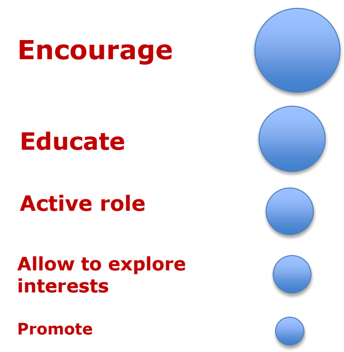
This section primarily focuses on three major areas: STEM supply, STEM pipeline, and infrastructure and government.

STEM Supply

What factors affect STEM supply? What roles do families play in increasing the number of people interested in STEM fields? How about educators? What are the major challenges affecting the supply of STEM workers? Answers to these questions are organized by addressing the role of families and educators, as well as other factors affecting the STEM workforce supply. A detailed review of associated challenges follows.

What roles should families play? Should parents be given incentives to make STEM occupational choices for adults or children in the family? Nearly 82 percent of respondents said yes to this question.

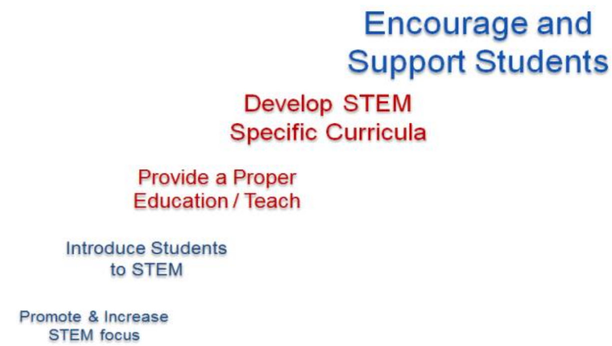




What specific role should parents play? BERC received over 100 comments from community leaders. They are listed in order of importance below (see appendix for details). Many respondents suggested parents should encourage children to steer toward STEM careers and studies in the STEM curricula. A review of comments suggests many forms of encouragement highlighted by community, including encouraging children (1) to be curious about STEM fields, (2) to excel academically, and (3) to explore STEM career paths.

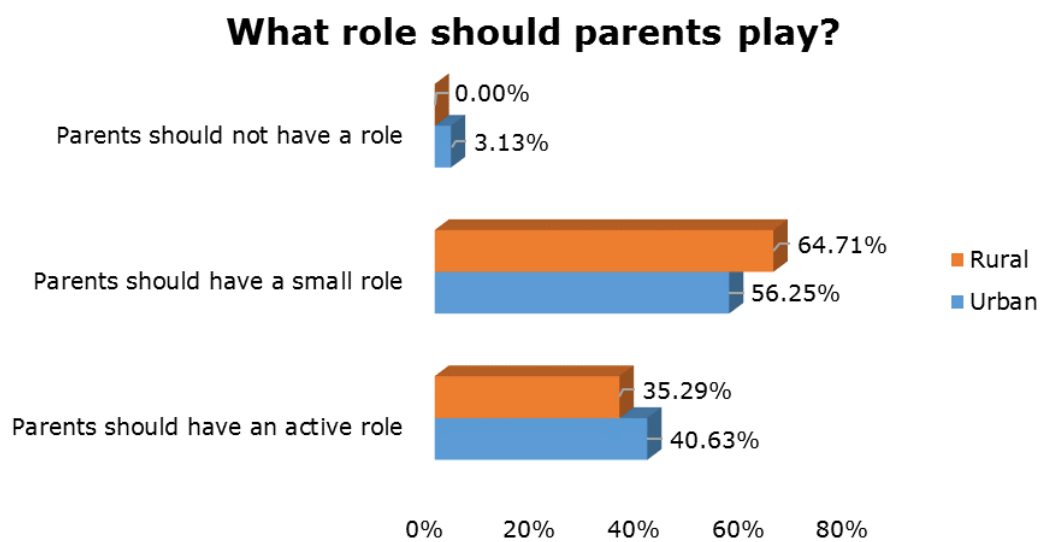
The second highly discussed keyword is educate. Under this sub-topic, parents were given an important role in educating children about STEM career opportunities. This includes actively educating both themselves and their children about opportunities.

What kind of active roles can parents play? The comments varied widely from an advocacy role in promoting STEM occupations and curricula in the community and schools to carefully directing, mentoring, and partnering with students as positive role models.



The fourth discussion topic centers around allowing children to explore their own interests. This is somewhat similar to the encouragement discussed above.

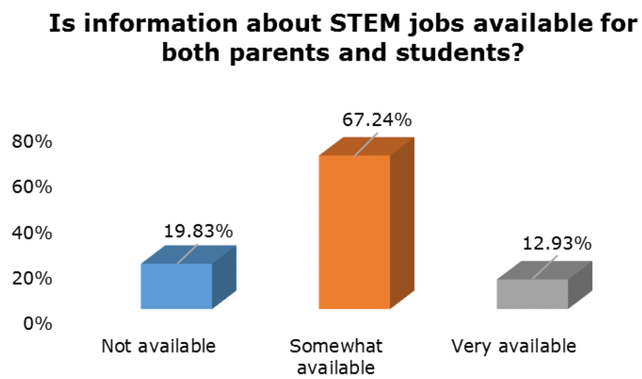
The fifth discussion is related to promoting STEM jobs and related career opportunities to children.

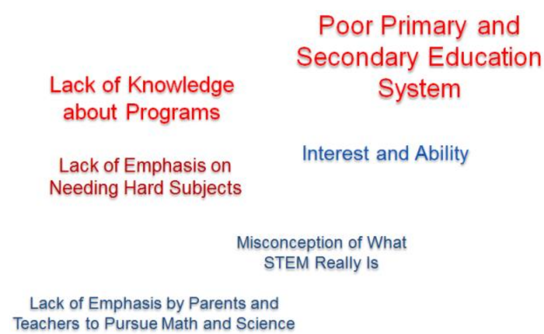


Reducing the 100 comments to three major categories in terms of what parents should do with regard to STEM occupations and careers, the following rural/urban differences emerge. Overall, 41 percent of respondents from urban areas assign an active role to parents in directing their students, compared with 35 percent of respondents from rural areas. Regions considered urban include the greater Memphis area, northern middle Tennessee, east Tennessee, and southeast Tennessee. The other five regions are reclassified as rural.

What roles should educators play? BERC received more than 100 comments on the role educators should play in addressing STEM workforce supply issues. The top five discussions center around encouraging and supporting students, developing STEM-specific curricula, providing a proper education, introducing students to STEM, and increasing STEM focus. The rural/urban difference with regard to the role of educators in the supply of STEM workers is significant, with 50 percent of respondents from urban areas assigning educators a large role in the supply of STEM workers. Is the educational system encouraging students to pursue a STEM degree? Only seven percent of respondents indicated there is strong encouragement. One in five respondents sees no encouragement at all, while 70 percent see some encouragement. How much of an emphasis is put on educators to teach STEM skills? Only 20 percent see strong emphasis, while 35 percent indicate either weak or very weak emphasis on educators to teach STEM skills.

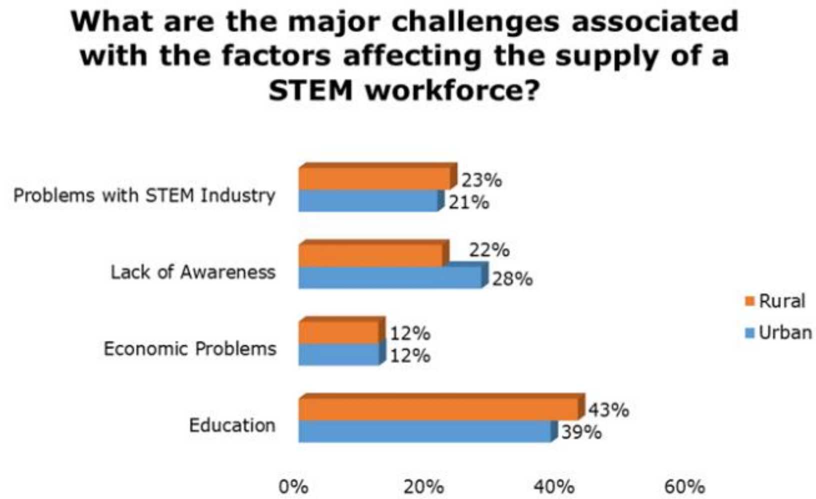
Information about STEM jobs. Do we have knowledge about STEM occupations? According to respondents, information about STEM jobs is not readily available to parents and students. Only 13 percent argued otherwise.





Major challenges associated with the supply of STEM workforce. The final question regarding the supply of STEM workforce was about the challenges Tennessee faces. Survey respondents generously contributed to this section with more than 200 comments. Of these comments, the following six stand out: poor primary and secondary education systems; lack of knowledge about programs; lack of interest and ability; lack of emphasis on the necessity of difficult subjects; misconception of what STEM is; and lack of parents' and teachers' emphasis on pursuit of math and science.

Is there a rural/urban difference on this issue? BERC identified four major themes from the comments. Community stakeholders from both urban and rural regions identified the education system as a primary challenge in the supply of STEM workers. This problem is more of an issue in the rural regions. The second reason Tennessee has challenges in STEM workforce supply is lack of awareness. Urban regions consider this a reason more often than rural areas. The third critical issue is related to problems with the STEM industry itself. According to community stakeholders, the primary reason for STEM workforce supply challenges is the lack of coordination between industry and educators. Furthermore, because of the movement of high-tech jobs overseas, there is a lack of opportunities in many areas.



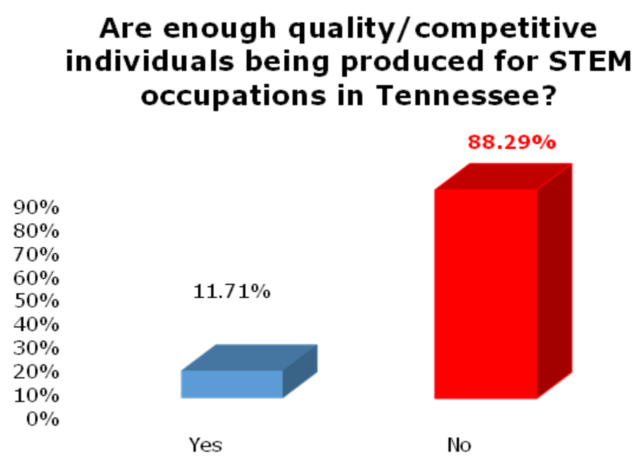
"Tennessee's economic future requires a workforce capable of meeting the expectations of employers. Those expectations include more employees with skills in science, technology, engineering, and math (STEM) in order to be competitive in the global economy. The research conducted by Dr. Murat Arik, professor and director of Middle Tennessee State University's Business and Economic Research Center, points to the need for STEM-related skills required by employers. The demand for these skills will grow exponentially in the years to come. Therefore, it becomes imperative that we all work together to assure more of our workers are STEM skilled."

—Patrick Geho, Mind2Marketplace board member and state executive director of the Tennessee Small Business Development Center at Middle Tennessee State University

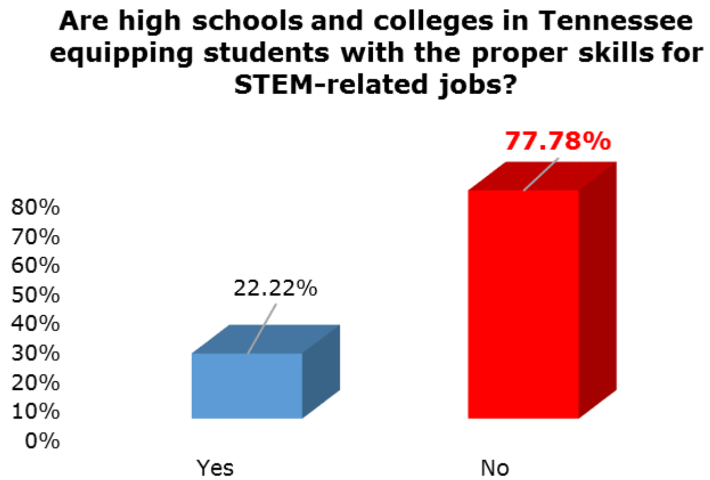
Chapter 4

STEM Pipeline and Challenges

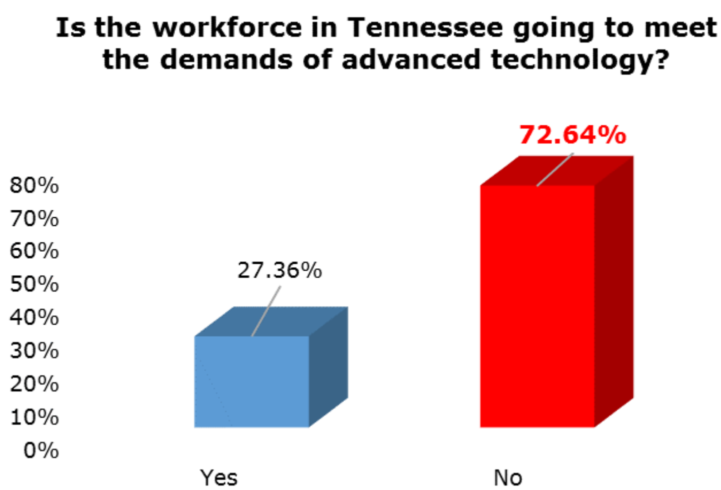
This chapter focuses on the supply side of STEM workforce challenges. It primarily looks at whether the educational system produces the necessary number and quality of graduates to meet the demand in the market. Are enough quality/competitive individuals produced for STEM occupations in Tennessee? An overwhelming percent of community stakeholders (nearly 90 percent) indicated that the Tennessee education system does not produce enough quality/competitive individuals. Only 12 percent suggested otherwise.



Are high schools and colleges in Tennessee equipping students with the proper skills for STEM-related jobs? This is a more targeted question assessing the performance of high schools and colleges in Tennessee. The answer is similar to that of the previous question: nearly 78 percent of community stakeholders said no. About 22 percent of respondents indicated the school system is producing enough high-quality graduates in Tennessee.



Is the workforce in Tennessee going to meet the demands of advanced technology? This question goes to the heart of efforts in Tennessee to promote the advanced manufacturing and healthcare information technology sectors. Does Tennessee have the necessary infrastructure to produce a skilled workforce to meet the technology challenge? Three out of four community stakeholders think the Tennessee workforce is not ready to meet advanced technology demands.



How many employees in STEM occupations have STEM degrees? In previous chapters this report discussed the implications of degree mismatch in STEM occupations and the oversupply of low-skilled STEM workers in Tennessee. The survey included a question regarding the degrees of current STEM employees. According to survey results, about 65 percent of STEM workers have a STEM degree.

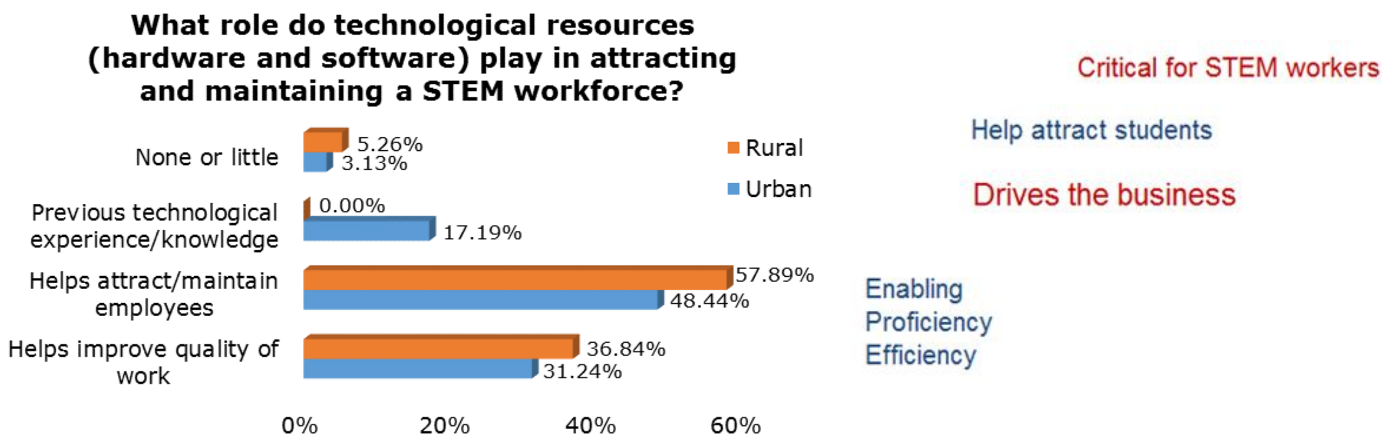
STEM pipeline–related challenges. What challenges are related to the STEM pipeline? Why should we care? Chapter 2 presented a host of indicators regarding the STEM pipeline in Tennessee. The STEM pipeline faces a series of challenges including math proficiency. Community stakeholders see other, similar challenges. There is the issue of getting students interested in STEM fields. The second critical challenge is transition—the lack of connection between education and employment. The lack of communication between business and higher education is closely associated with this transition challenge, which affects the STEM pipeline and, in turn, Tennessee's sustainable economic competitiveness. Other critical challenges include the lack of funding for STEM training, lack of cultural awareness, demand exceeding the supply, and the subsequent adjustment problem, lack of available information about existing STEM programs, and lack of knowledge and skill among workers, trainers, and educators.

How do some of these challenges appear across the rural/urban divide? For the sake of simplicity, we collapsed all comments into four major categories across the rural/urban divide: market problems, education problems, lack of knowledge/interest, and community problems. The largest rural/urban divide is in the area of lack of knowledge/interest, with nearly a 15 percentage-point difference. Urban respondents are more likely to suggest that lack of student interest in STEM fields is a major issue. The second category is market problems which is more pronounced in rural areas. Finally, the quality of the educational system is a challenge prevalent in both rural and urban segments.

Chapter 5

Infrastructure and Government Challenges

What role do infrastructure and government play in addressing challenges facing the STEM workforce in Tennessee? The survey included several open-ended questions on resources, incentives, programs, funding, partnerships, and overall challenges. What role do technological resources (hardware and software) play in attracting and maintaining a STEM workforce? Not surprisingly, answers to this question centered on the following: these resources (1) are critical for STEM workers, (2) help attract students to STEM fields, (3) virtually drive business competitiveness and profitability, and (4) improve proficiency and efficiency among both businesses and individuals.

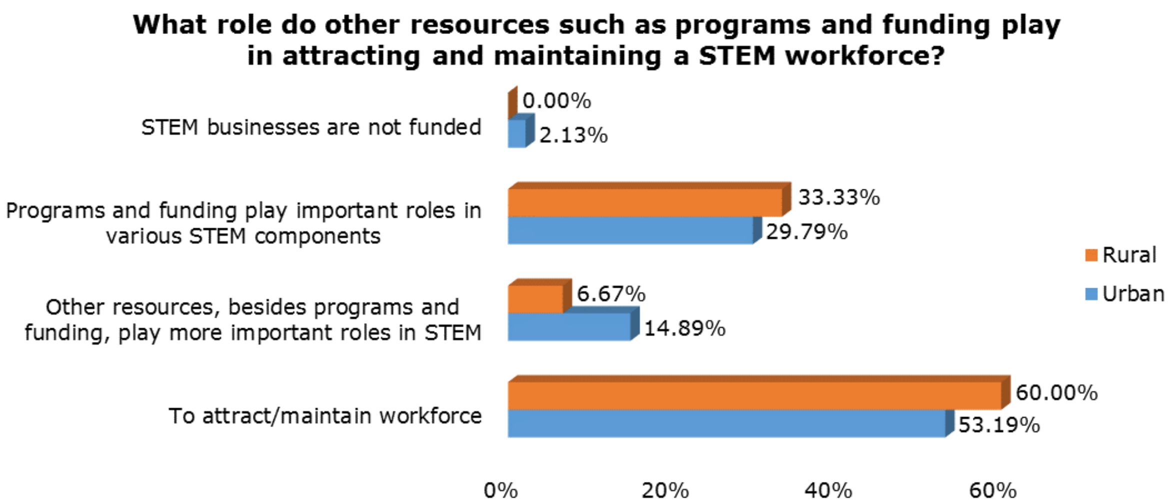


There is no doubt about the role technological resources play in attracting professionals to rural areas. Similarly, in rural areas, such resources improve STEM workers' quality of life. What is strikingly different between rural and urban areas is the role of STEM workforce experience and knowledge. Previous technology experience trumps up-to-date technology and resources in importance for maintaining a STEM workforce in urban areas.

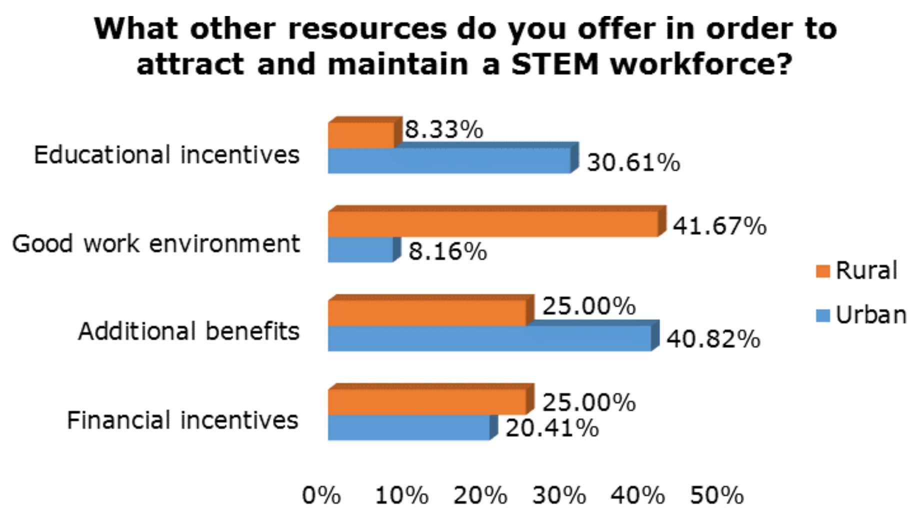
What role do other resources such as programs and funding play in attracting and maintaining a STEM workforce? In response to this question, 31 percent of comments indicated that funding and programming are critical for maintaining a STEM workforce, 11 percent highlighted the importance of these resources in attracting and retaining students, and 10 percent mentioned the role of these programs in ensuring a steady supply of skilled workers.

Why are these programs so critical for a STEM workforce? Respondents explained that these programs and funding:

- provide early exposure to STEM,
- build the STEM workforce,
- make education more affordable,
- enable potential STEM candidates, and
- encourage STEM engagement.



Does the impact of these programs and funding sources differ across the urban/rural divide? In rural regions, such programs and funding sources are particularly important in attracting and retaining a STEM workforce.

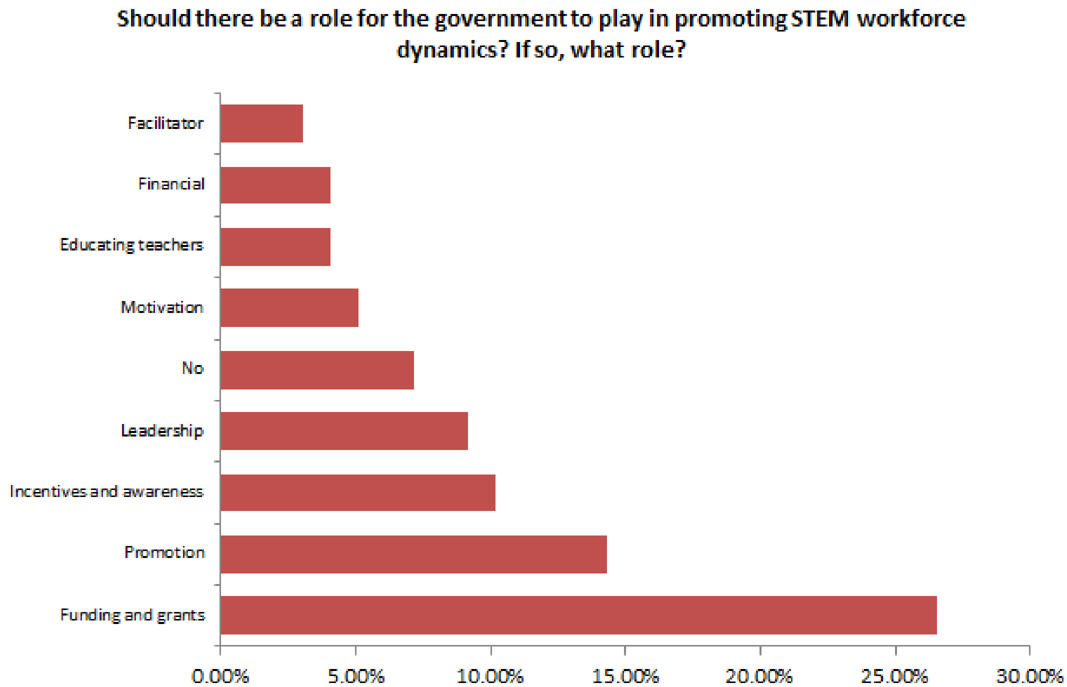


What resources do companies offer in order to attract and maintain a STEM workforce? Companies offer many resources and incentives to attract and maintain a STEM workforce, including (1) platform for success including continuing education, (2) good wages and salaries, (3) flexible work schedule, (4) promotion, (5) tuition assistance, and (6) workshops.

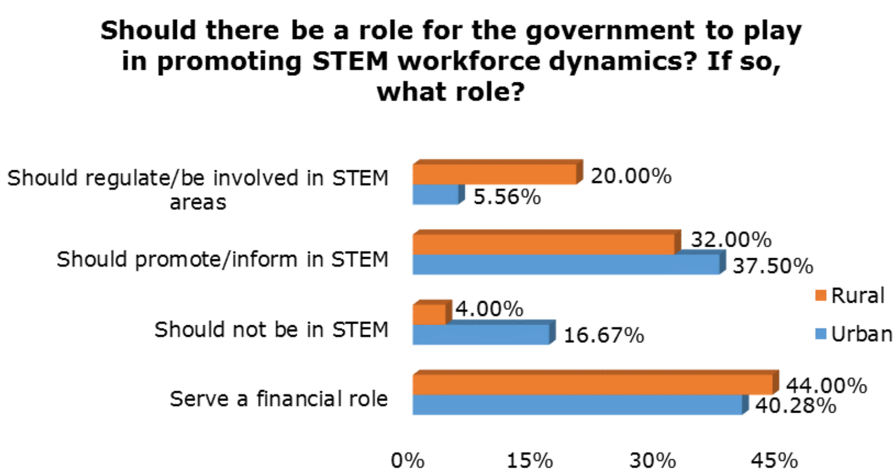
Is there a rural/urban difference in what companies offer to attract and retain a STEM workforce? Yes. The critical rural/urban difference is that in rural areas, companies overwhelmingly offer a good work environment and financial incentives. In the urban environment, the incentive structure is different: companies primarily offer educational incentives and additional benefits.

What do you think about the technology infrastructure? Nearly 65 percent of respondents rated Tennessee's technologically trained work environment as average. Only 16 percent suggested it is weak or very weak. Nearly 20 percent rate it as strong or very strong.

Role of government. What role should government play in promoting STEM workforce dynamics? This question received somewhat mixed responses from stakeholders. Nearly one-third of the comments assigned a funding and grant agency role to the government. Nearly 10 percent indicated government should have no role in the STEM workforce area. Other major roles of government in promoting STEM workforce dynamics cited were providing leadership, providing incentives, and promoting awareness.



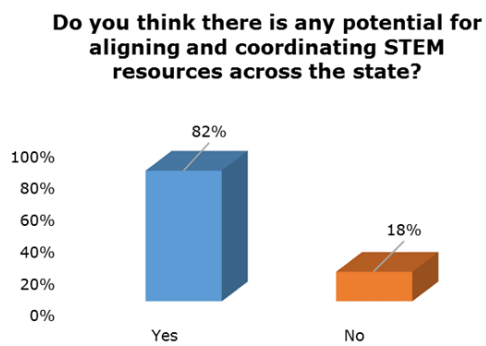
The desired role of government varies greatly across the urban/rural divide. For example, about 20 percent of comments from rural areas suggest government should regulate or be involved in the STEM workforce area. Relatively few comments from urban areas suggested similar government roles. Comments from urban areas expressed the opposite of rural responses: 17 percent do not recognize a role for government in STEM workforce areas. The major emphasis of businesses in urban regions believe government should create awareness about STEM dynamics and be a source of information.



What are potential ways to engage business, industry, and other community partners in advancing STEM? All respondents believe in engaging different stakeholders in advancing STEM. Out of 50 recommendations, the following rank highest in order of importance: making connections between educational institutions and workforce needs, visibility, mentorships, business-education partnerships, career connections, incentives for collaboration, industry presence in schools, regional skill panels, and STEM tax incentives.

Responses	Total	Percent
Making connections between educational institutions and workforce needs	7	14.29%
Visibility	6	12.24%
Mentorships	3	6.12%
Business-education partnerships	2	4.08%
Career connections	2	4.08%
Incentives for collaboration	2	4.08%
Industry presence in schools	2	4.08%
Regional skill panels	2	4.08%
STEM tax incentives	2	4.08%

Do you think there is potential for aligning and coordinating STEM resources across the state? About 82 percent of respondents indicated there is potential for coordination of STEM resources across the state.



Responses	Frequency	Percent
Government itself	9	11.25%
Funding	6	7.50%
Lack of awareness	4	5.00%
Budget cuts	3	3.75%
Lack of buy-in by educators and politicians	3	3.75%
Personal agenda and greed	3	3.75%
Qualified faculty	3	3.75%
Accountability in schools	2	2.50%
Fragmented efforts	2	2.50%
Lack of vision	2	2.50%
Limited government role	2	2.50%
Waste of money on non-productive areas	2	2.50%

What major challenges are associated with the STEM infrastructure and the government's role in promoting STEM workforce dynamics? This question received about 80 different comments, each highlighting a particular aspect of government, STEM industries, financial resources, and educational systems. The comments were often critical of the role of government in advancing

STEM dynamics. For example, many comments highlighted the lack of clear governmental vision and leadership in STEM areas.

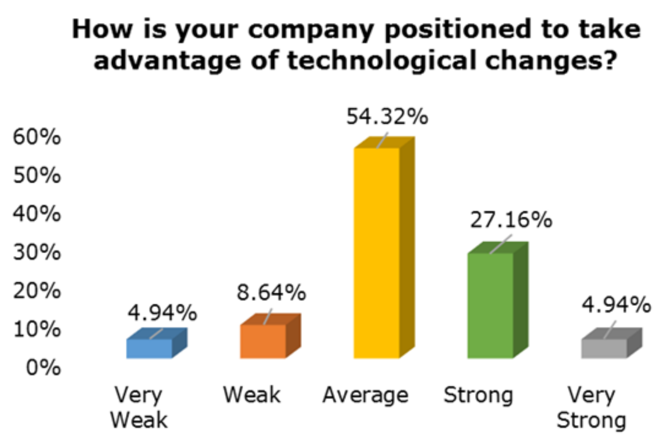
> *"As we work together to build a prosperous future in Tennessee, we know that innovation is crucial for our long-term economic success. The work of Dr. Arik and his team helps us frame both opportunities and challenges statewide as we seek to grow the science, technology, engineering, and math economy so crucial to nurturing innovation. The facts and opinions documented in the report offer encouragement and motivation to continue this important work."*
>
> —Charles E. Shoopman Jr., Mind2Marketplace board member and assistant vice president of the University of Tennessee Institute for Public Service

Chapter 6

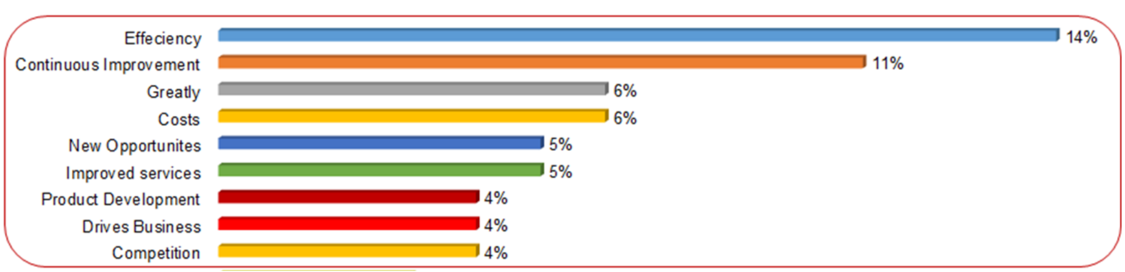
Challenges to Businesses, Future Expectations, and STEM Supply and Demand

Challenges to Businesses

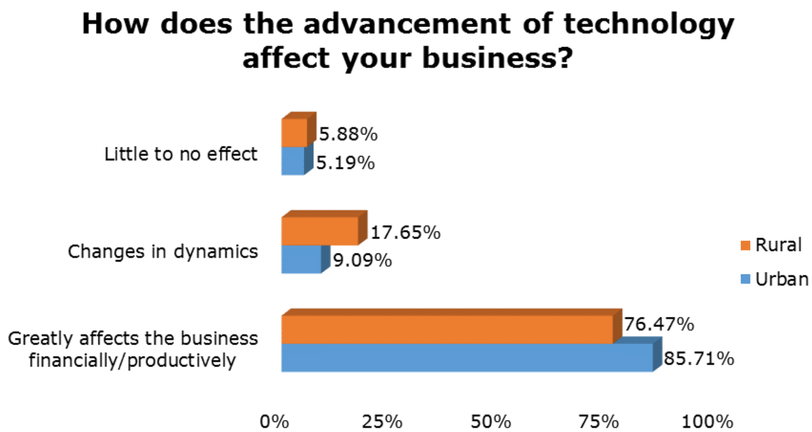
Are businesses in Tennessee positioned to take advantage of technological changes? The STEM survey fielded several questions about businesses associated with STEM-related issues. Many businesses (about 54 percent) rate themselves as average in taking advantage of technological changes. Nearly 15 percent rate themselves as weak or very weak. Combined, more than two in every three companies are not strongly positioned to take advantage of technological changes.



How does the advancement of technology affect your business? Community stakeholders indicated efficiency was most affected by the advancement of technology. Continuous improvement was also cited as a significant effect, followed by lower costs, new opportunities, improved services, and product development.

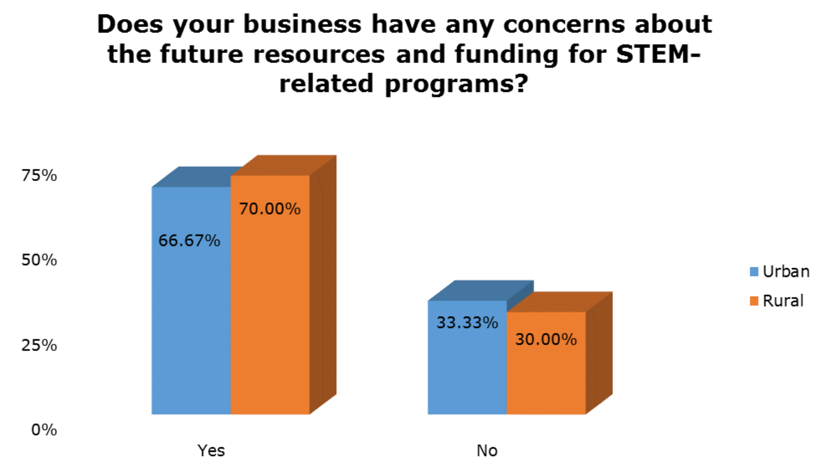


Both urban and rural respondents agree that the advancement of technology greatly affects their business either financially or in terms of productivity. More rural than urban respondents indicated technology would change the dynamics of their business. A small percentage of both urban and rural respondents argued technology would have little to no effect on their business.

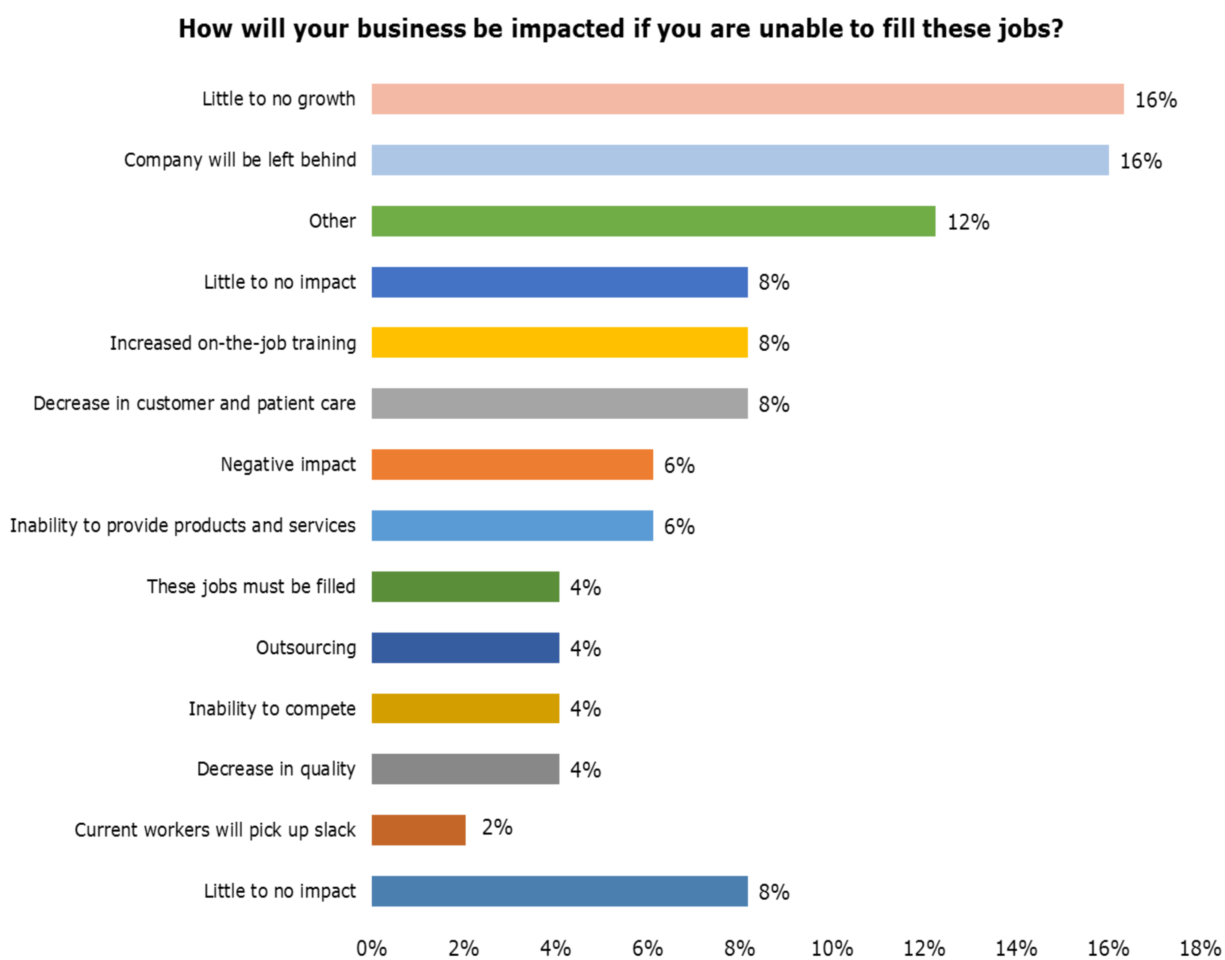


Does your business have any concerns about future resources and funding for STEM-related programs? Community stakeholders responded that they had several concerns about future resources and funding for STEM-related programs. Eighteen percent indicated funding was a concern, while 15 percent were concerned about the absence of a properly trained workforce. Eight percent cited the lack of cost-effective infrastructure, and five percent were concerned about keeping up with technological advancements. The negative outlook for STEM workforce dynamics and increasing tuition costs were both mentioned by three percent of respondents as possible concerns for the future. On the other hand, 30 percent of respondents said they had no concerns about future resources and funding for STEM-related programs.

Looking at this issue in a regional context reveals no significant difference in the perceptions of urban and rural respondents. Though more rural than urban respondents indicated future concerns and more urban than rural respondents had no future concerns, differences were not significant.

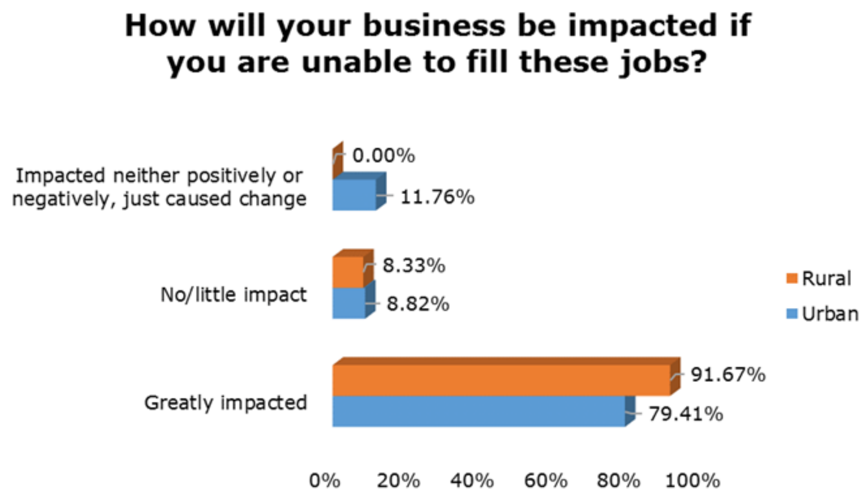


Survey respondents indicated they expect to see about a three-percent growth in STEM-related jobs at their companies over the next six to ten years.

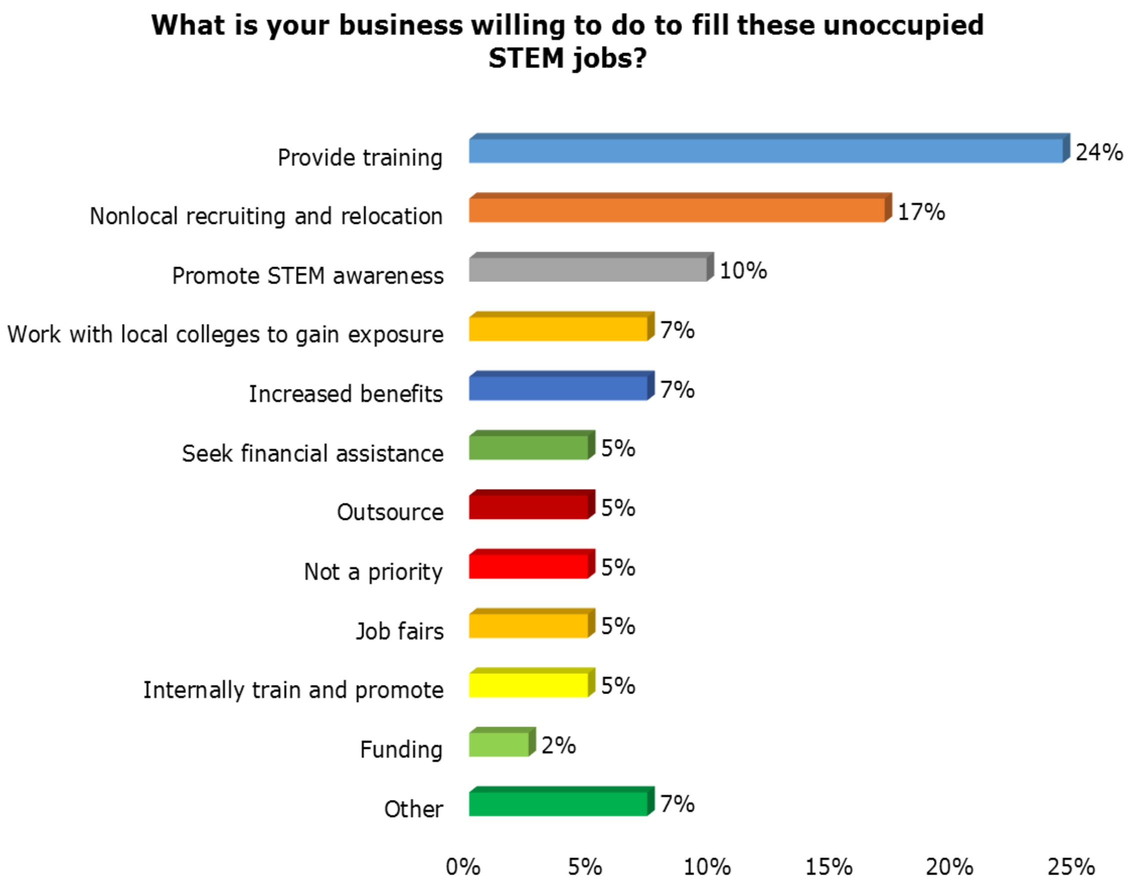


What happens if these businesses cannot fill these STEM-related positions? Top answers to this question include "little to no growth," "company will be left behind," "little to no impact," "increase in job training," and "decrease in customer and patient care." Other less frequent comments are similar.

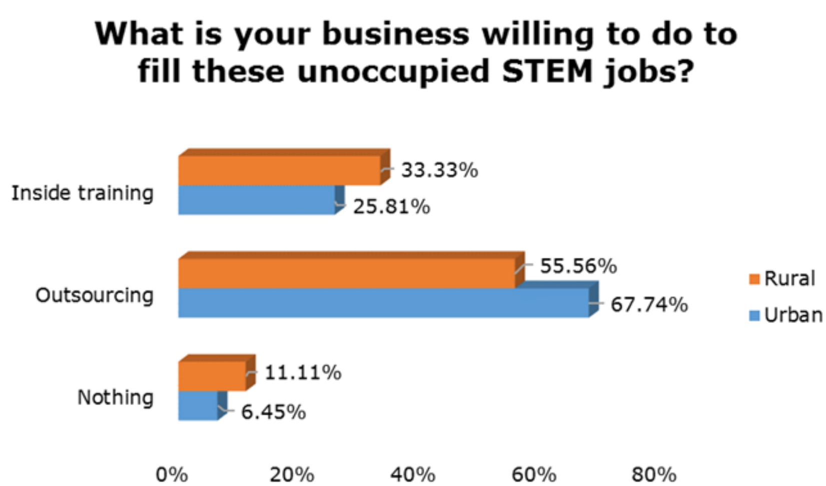
What is the rural/urban difference on this question? Nearly 92 percent of rural businesses and 80 percent of urban businesses indicated their businesses will be greatly impacted if these STEM positions go unfilled—a nearly 12 percentage-point difference.



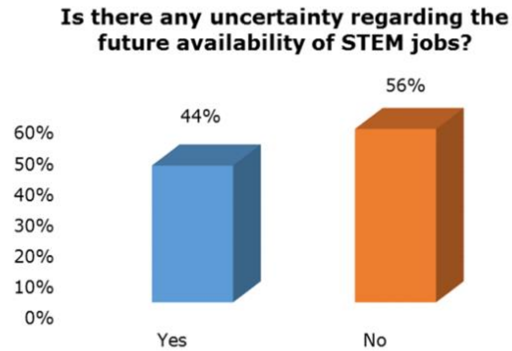
A subsequent question on the subject was "What is your business willing to do to fill these unoccupied positions?" The top five answers include "provide training," "non-local recruiting and relocation," "promote STEM awareness," "work with local colleges to gain exposure," and "increased benefits."



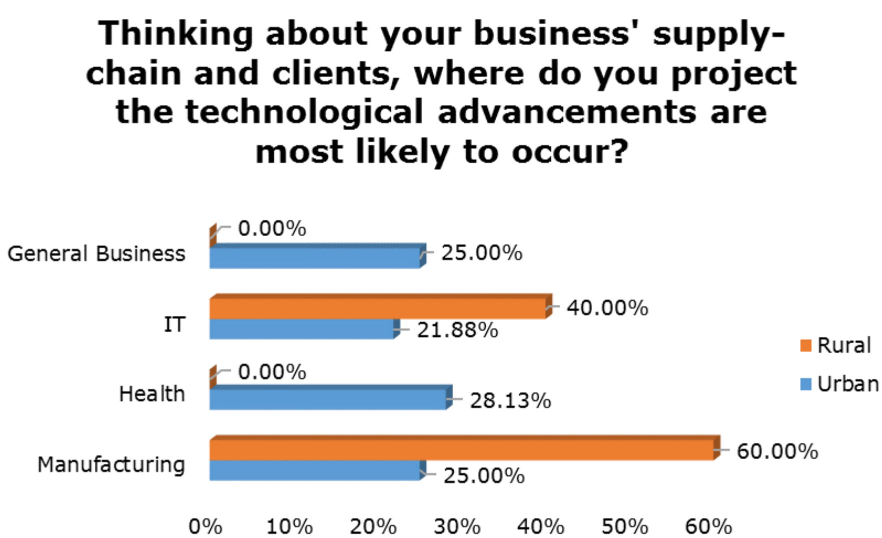
What is the rural/urban divide on this question? A significant percent of businesses in both rural and urban areas suggests outsourcing with more than a 12 percentage-point difference between rural and urban businesses. One in every three businesses in rural regions indicated they would conduct inside training; this ratio is one in every four businesses in urban areas.

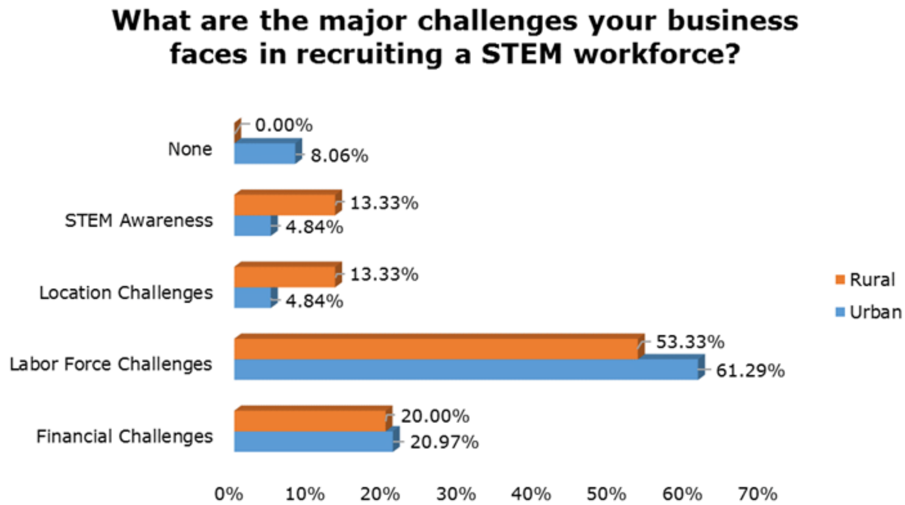


Is there any concern regarding the future availability of STEM jobs? The majority of businesses do not see any uncertainty, but 44 percent think otherwise.



Where do businesses see technological development in their supply chain? A glance at responses suggests four major areas: manufacturing, IT (information technology), health, and general business. There is a striking rural/urban difference across these categories. For example, 60 percent of rural responses indicated manufacturing will the major sector experiencing technological shift, while only 25 percent of businesses from urban regions think similarly. The health and general business areas exhibit a reversed trend. An overwhelming percent of urban respondents foresee the greatest advancement in the health and general business sectors.

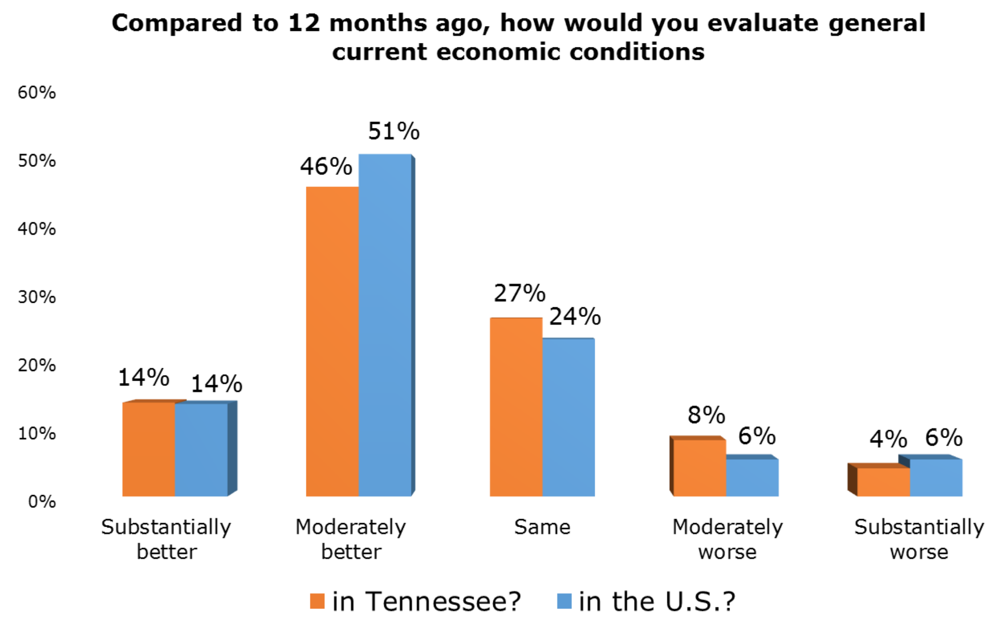




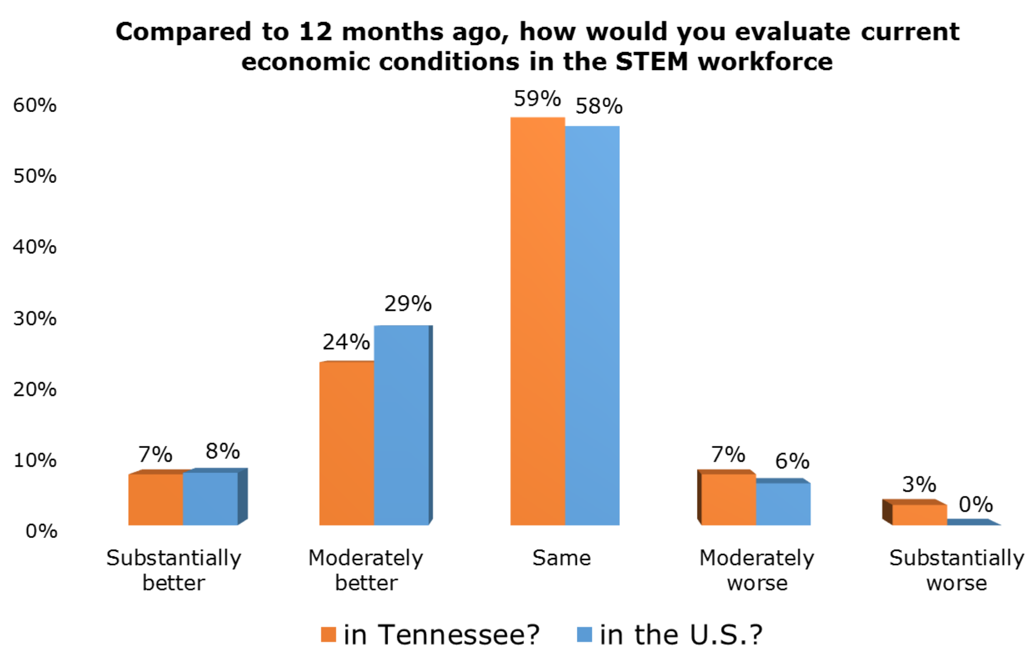
Finally, the survey asked about major challenges community stakeholders face in recruiting a STEM workforce. Critical "labor force challenges" are more pronounced in urban than in rural areas. Rural businesses face more challenges associated with STEM awareness and with location.

Future Expectations

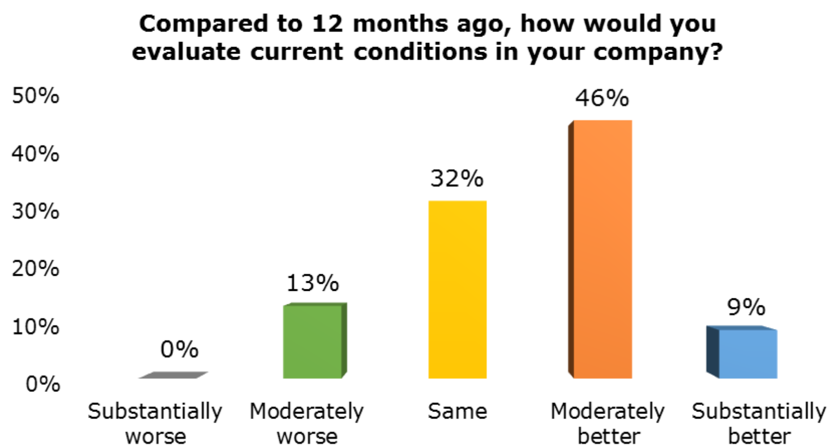
BERC surveyed community stakeholders in 2014 regarding their perspective on past, current, and future economic conditions in general, and national and local STEM-related industries in particular. A total of 210 stakeholders from the state responded to the survey. Compared to 12 months ago, how would you evaluate current economic conditions? According to community stakeholders, Tennessee and the United States in general are performing moderately better than a year ago. Current economic conditions are better for Tennessee for 60 percent of respondents versus 65 percent for the nation. Of the 72 respondents, nine believed that economic conditions in Tennessee were moderately or substantially worse than they were a year ago.



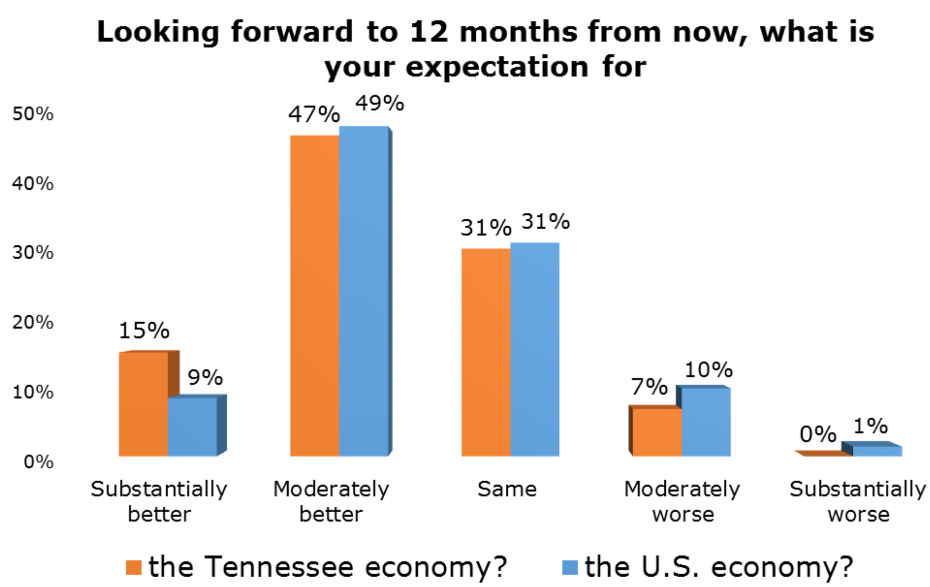
Compared to 12 months ago, how would you evaluate current economic conditions in the STEM workforce? Community stakeholders see current economic conditions in the STEM workforce as the same as last year in both the state and the nation. About 59 percent see Tennessee STEM economic conditions as the same, and 58 percent see the United States as the same in this regard.



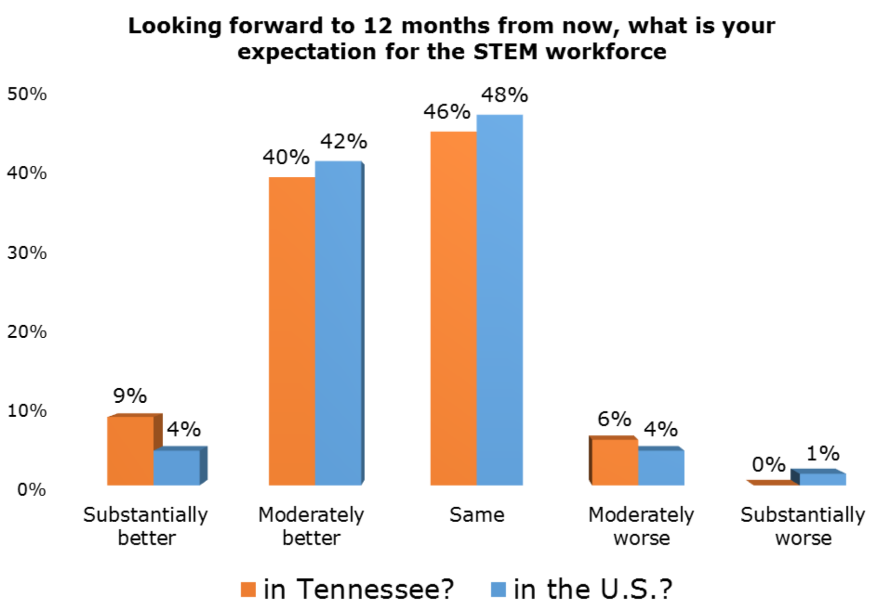
Compared to 12 months ago, how would you evaluate current conditions in your company? Of the community stakeholders, 46 percent responded that their company was performing moderately better than a year ago, and 9 percent said substantially better. This shows that overall 55 percent of respondents believed their company's conditions had improved from a year earlier. None believed their company was substantially worse than the year before.



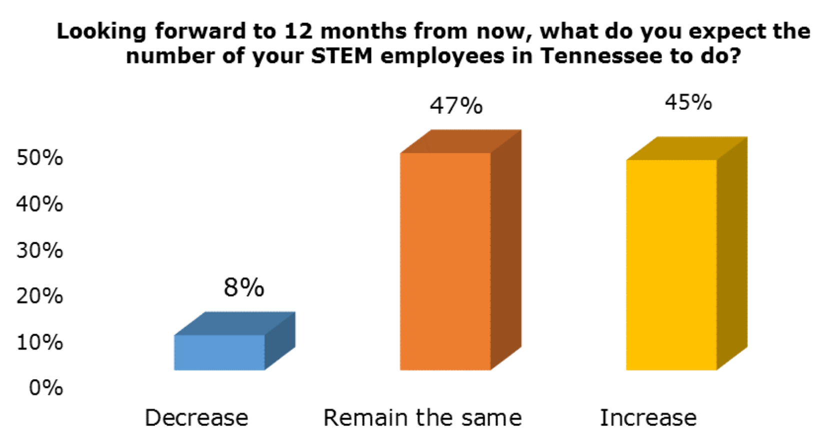
Looking forward to 12 months from now, what are your expectations for the U.S. economy and the Tennessee economy? According to respondents, 63 percent saw the Tennessee economy improving in the next year and 57 percent saw the U.S. economy improving. Fifteen percent foresaw that the Tennessee economy would improve substantially.



Looking forward to 12 months from now, what are your expectations for the STEM workforce in the U.S. and Tennessee? Community stakeholders were more reserved regarding their expectations for the future of the STEM workforce in both the U.S. and Tennessee. Ninety percent predicted the U.S. STEM workforce would stay the same or moderately improve, and 85 percent expected the Tennessee STEM workforce to stay the same or moderately improve.



Looking forward to 12 months from now, how do you expect the number of your STEM employees in Tennessee to change? Community stakeholders believed the number of their STEM employees would increase or remain the same in the next year. Forty-seven percent said it would remain the same, and 45 percent responded that it would increase.

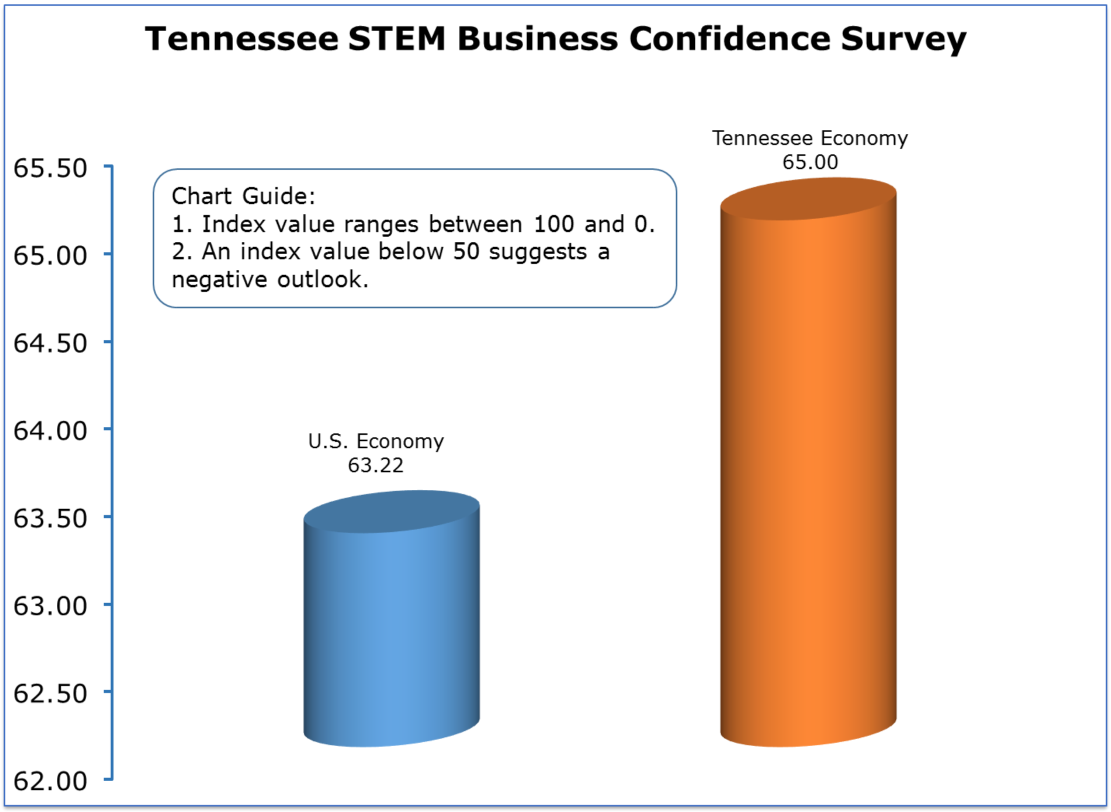


What are your firm's profit expectations from STEM-related occupations in Tennessee for the next 12 months? A majority of community stakeholders believed their profit expectations would remain the same in the next year.

STEM Business Confidence Survey. The *STEM Business Confidence Survey* is the average value of standardized scores for the three survey questions highlighted above. These are (1) current general economic conditions compared to a year ago, (2) future expectations for the overall economy, and (3) future expectations for the STEM workforce.

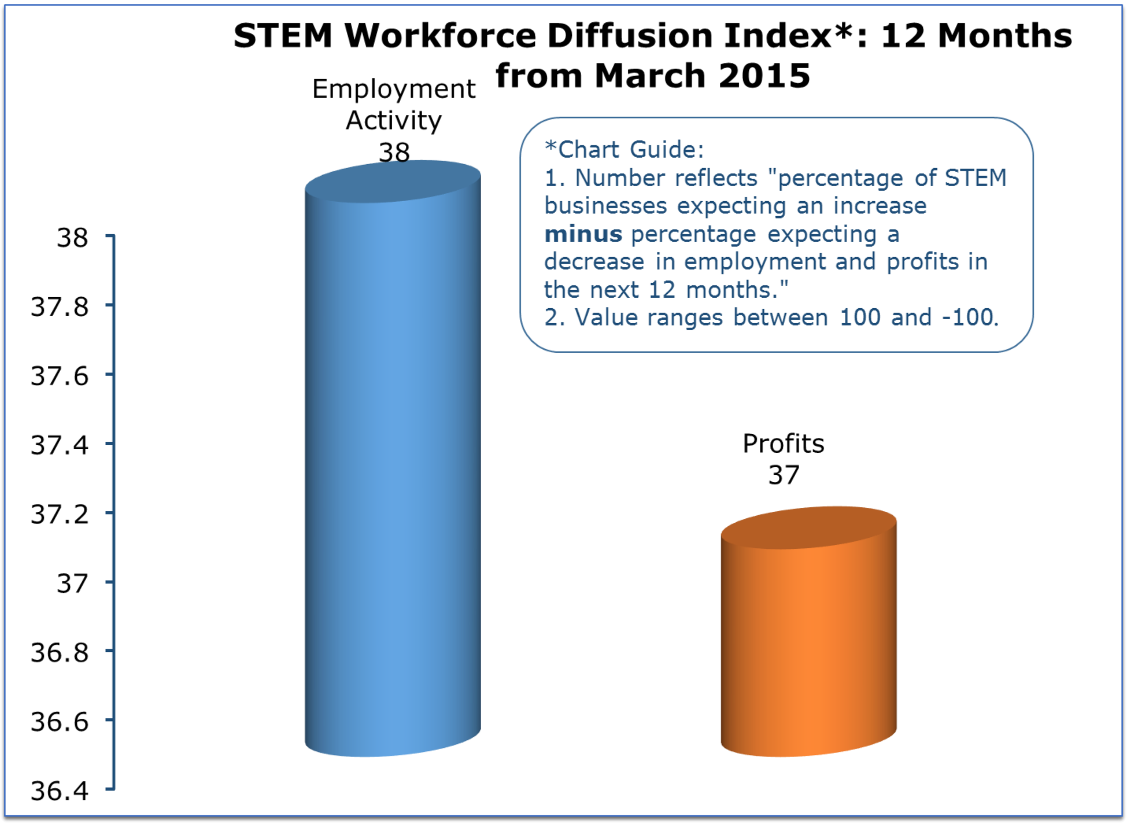
The business outlook is positive for both the U.S. and Tennessee economies. An index value of 50 or higher suggests a positive outlook. These figures are comparable to the CEO business confidence survey conducted quarterly by the Conference Board.[3] The 2015 second-quarter reading of the Conference Board CEO Confidence Index is 58, suggesting a positive outlook. The STEM business outlook for Tennessee is 65, almost two points higher than the STEM business outlook for the nation.

[3] www.conference-board.org.



Hiring and profit expectations. The extensive analysis of STEM workforce dynamics suggests hiring and profit will continue to increase in Tennessee and across the nation. Community stakeholders suggest this trend will continue. The employment activity index, which ranges from -100 to +100, with -100 as very negative and +100 as very positive, shows moderate hiring expectations for the year following March 2015. This index number is the difference between the percent of community stakeholders expecting an increase in hiring and the percent expecting a decrease. The current reading of the employment activity index is 38. The index is higher than that of the business outlook survey for the manufacturing industry conducted by the Federal Reserve Bank of Philadelphia.[4] The August 2015 reading of the Federal Reserve Bank survey is 20, suggesting higher than average economic activity in STEM-related businesses. In addition, there is a positive profit expectation for STEM-related business.

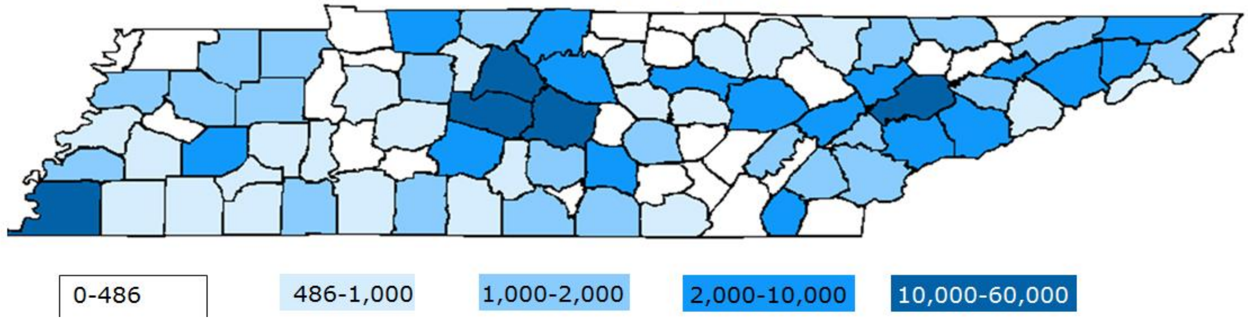
[4] www.phil.frb.org.



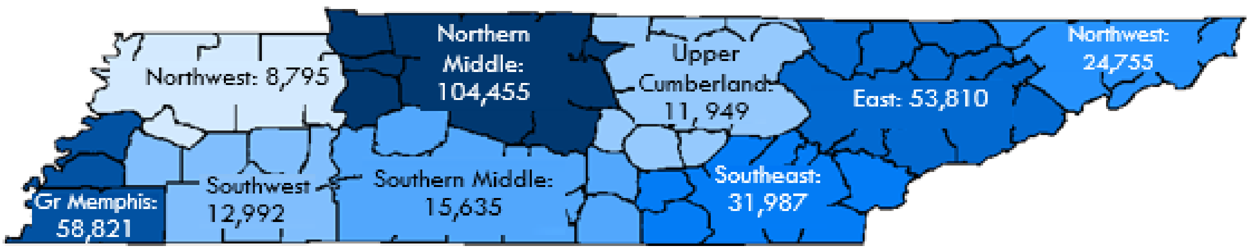
STEM Supply and Demand

How many STEM jobs does Tennessee have? What is the projected growth rate of STEM jobs in the next 10 years? How does supply meet the demand for STEM jobs in Tennessee? What are the key drivers of growth in STEM jobs? Using a number of data sources including the STEM survey, this section projects STEM supply and demand conditions for the next 10 years. As presented in chapter 2, the estimate of STEM workforce in Tennessee numbers was 324,328 in 2014. This figure is used as a baseline job number for forecasting. The following maps highlight the distribution of STEM jobs by both county and region in Tennessee.

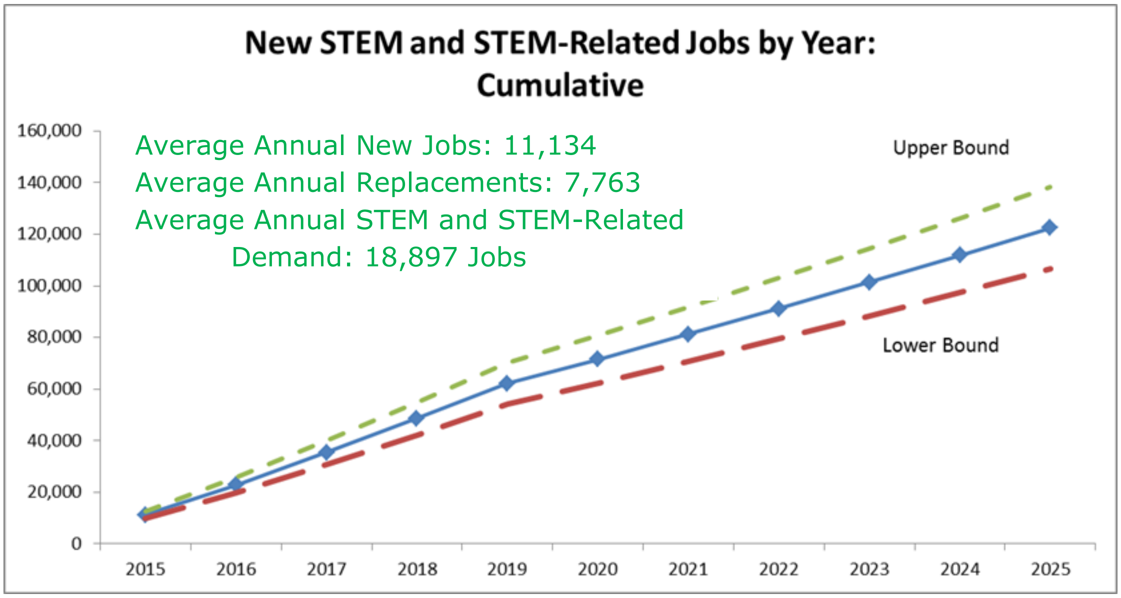
STEM Jobs by County (2014)



Distribution of STEM Jobs by Region



Over the next ten to eleven years, the average annual growth rate of STEM jobs in Tennessee is estimated to be around 3.43 percent. Annual average growth rates are derived from the STEM business survey. Total number of STEM jobs is estimated from the American Community Survey (ACS). This forecast includes not only new jobs but also replacement jobs due to retirement. Total number of replacement STEM jobs between 2014 and 2025 is estimated at around 85,392 in Tennessee. Using several data sources, between 2014 and 2015, Tennessee businesses will add 122,477 new STEM jobs. Adding the total number of replacement STEM workers due to retirement brings the total demand for STEM workers to 207,869. This translates into an average annual demand of 18,897 STEM and STEM-related jobs.



What about the supply side? According to calculations from the University of Tennessee Center for Business and Economic Research, annual average STEM-degree production in Tennessee is estimated at around 11,195. According to supply-and-demand estimates and replacement numbers, the supply-to-demand ratio is estimated at around 0.59, suggesting that 41 percent of demand will be unmet locally. Currently 65 percent of STEM job holders have a STEM degree. In many cases, this implies the workers in the STEM jobs are not properly qualified.

Average Annual ***New*** STEM and STEM-Related Jobs	**11,134**
Average Annual ***Replacement***	**7,763**
Total Demand (Annual Average)	**18,897**
Total Supply (Annual Average Degree Production in STEM)*	**11,195**
Supply-to-Demand Ratio	**0.59242**

*Estimated from Academic Program Supply and Occupational Demand Projections: 2012-2025, by UT Center for Business and Economic Research, 2014

Total Demand by Educational Attainment (Annual Average)

Degree Level	Percent Breakdown	Total Jobs
HS/VD/AS	28.85%	5,452
BA	59.62%	11,266
MA+	11.54%	2,181

Total Supply by Educational Attainment Level (Annual Average)*

Degree Level	Percent Breakdown	Total Degrees
Less than BA	29.80%	3,336
BA	57.28%	6,412
MA+	12.93%	1,447

Degree Level Supply to Demand Ratios

Less than BA	0.6119
BA	0.5691
MA+	0.6635

*Estimated from Academic Program Supply and Occupational Demand Projections: 2012-2025, by UT Center for Business and Economic Research, 2014

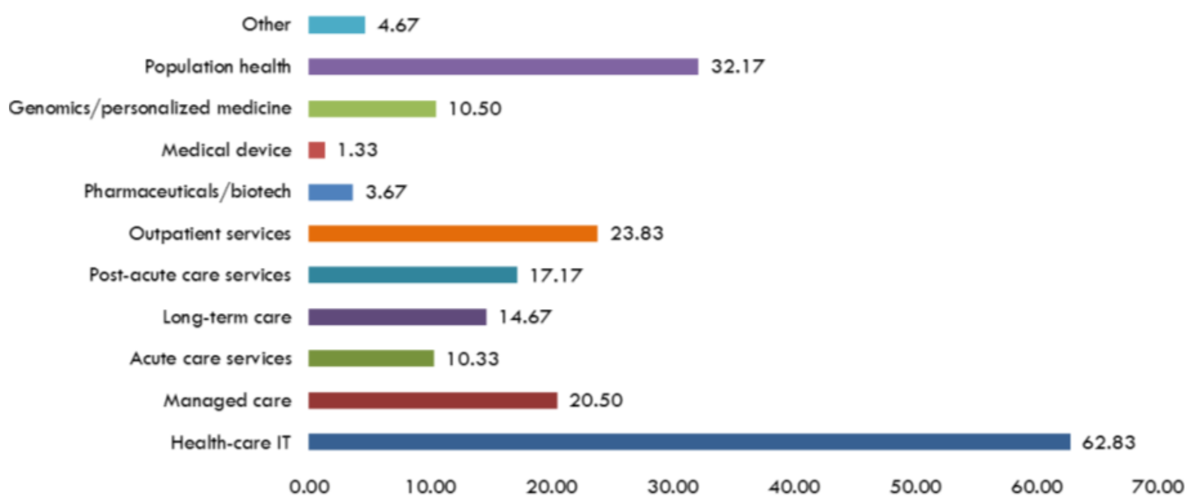
What is the educational attainment breakdown of total STEM workforce demand and supply? To provide an estimate of the educational attainment breakdown of supply and demand, this report uses the BERC STEM survey and a report issued by the University of Tennessee Center for Business and Economic Research. On the demand side, about 60 percent of STEM jobs will require a bachelor's degree. On the supply side, 57 percent of STEM degrees are bachelor's degrees. From the annual average degree-level supply and demand ratios, the following picture emerges: less than bachelor's degree 61 percent; bachelor's degree 57 percent; and graduate degree 67 percent.

What are some of the drivers of growth in STEM occupations? Several sectors have been mentioned throughout the report, including health care, IT, and advanced manufacturing. This report particularly highlights two critical areas: (1) significant growth in some highly specialized occupations and (2) transformative changes in health care, increasing demand for STEM and STEM-related workers.

According to a report issued by the University of Tennessee Center for Business and Economic Research, the supply-and-demand ratio for certain STEM occupations is as low as 0.06, suggesting only 6 percent of demand is met by the supply. For example, the annual supply of environmental engineers is 39, while annual average demand for this job is 650, creating a

94 percent deficit. A recent study by Middle Tennessee State University's Business and Economic Research Center highlights a growing concern among Nashville healthcare industry CEOs regarding the availability of healthcare workers in the Nashville MSA, where the healthcare industry cluster has national prominence.

When asked which healthcare sectors promise growth, the top answer by a wide margin is the healthcare IT sector. Based on this, combined with the outlook for other sectors, the lack of available workforce in STEM fields may be a real damper on the growth of the medical technology and healthcare IT sectors.



"This research includes two distinct elements: 1) a survey of the state of the TN STEM workforce dynamics compared to peers and 2) a survey of stakeholders vested in the STEM economy across the state. The combined results present a clear picture of the gaps and challenges Tennessee faces in the marketplace for the quality jobs of the future. Any elected official, educator, or business person that relies on a STEM workforce will find this research informative and compelling."

—Tim Choate, Mind2Marketplace board member and president/CEO Bondware Inc.

Chapter 7

STEM Workforce Characteristics and STEM Index

STEM Workforce Characteristics

This chapter covers the segment of the survey in which respondents were asked to provide data on current occupations, wages, vacancies, educational requirements, certification requirements, and the difficulty of filling these occupations. Here BERC focuses on two key aspects: average wages and the difficulty of filling jobs.

What are the top STEM occupations by wage? The top 15 STEM occupations have an average wage ranging from $30 to $55 and fall under an assortment of occupational codes. The most lucrative STEM occupation is computer network architect (15-1143) with an average wage of $55. Four occupations tied for 15th, all with an average wage of $30: civil engineers (17-2051), economists (19-3011), information security analysts (15-1122), and surveying and mapping technicians (17-3031).

STEM Occupations Ranked by Average Wage

Occupational Code	Occupational Title	Average Wage	Rank
15-1143	Computer network architects	$55.00	1
15-2090	Miscellaneous mathematical science occupations	$50.00	2
17-2041	Chemical engineers	$45.00	3
11-9041	Architectural and engineering managers	$41.33	4
17-2081	Environmental engineers	$41.08	5
19-1010	Agricultural and food scientists	$40.00	6
17-2110	Industrial engineers, including health and safety	$38.33	7
17-2070	Electrical and electronics engineers	$37.50	8
17-2141	Mechanical engineers	$37.50	8
17-0000	Architecture and engineering occupations	$34.21	10
15-1131	Computer programmers	$31.92	11
15-113X	Software developers, applications and systems software	$31.88	12
11-0000	Management, business, and financial occupations	$30.99	13
15-0000	Computer and mathematical occupations	$30.69	14
17-2051	Civil engineers	$30.00	15
19-3011	Economists	$30.00	15
15-1122	Information security analysts	$30.00	15
17-3031	Surveying and mapping technicians	$30.00	15

What are the top STEM-related occupations by wage? The top 10 STEM-related occupations have an average wage ranging from $29.27 to $52.50, and most fall under the healthcare practitioners and technical occupations group, with only one occupation belonging to the architecture and engineering occupations group. The highest wages of all STEM-related occupations are group physicians and surgeons (29-1060), with an average wage of $52.50. The outlier, architecture and engineering occupations, ranks fifth and pays an average wage of $35. General healthcare practitioners and technical occupations rank 10th overall with an average wage of $29.27.

STEM-Related Occupations Ranked by Average Wage

Occupational Code	Occupational Title	Average Wage	Rank
29-1060	Physicians and surgeons	$52.50	1
29-1051	Pharmacists	$50.00	2
29-1122	Occupational therapists	$40.00	3
29-1127	Speech-language pathologists	$37.50	4
17-0000	Architecture and engineering occupations	$35.00	5
29-2030	Diagnostic related technologists and techicians	$35.00	5
29-1171	Nurse practitioners	$35.00	5
29-1071	Physicians assistants	$32.50	8
29-1031	Dietitians and nutritionists	$31.67	9
29-0000	Healthcare practitioners and technical occupations	$29.27	10

STEM Occupations Ranked by Difficulty of Filling

Occupational Code	Occupational Title	Difficulty of Filling (1=Extremely Easy) (10=Extremely Difficult)
11-3021	Computer and information systems managers	6
15-0000	Computer and mathematical occupations	6
17-3020	Engineering technicians, except drafters	6
19-0000	Life, physical, and social science occupations	6
15-113X	Software developers, applications, and systems software	6
11-9041	**Architectural and engineering managers**	**7**
17-0000	**Architecture and engineering occupations**	**7**
17-2041	**Chemical engineers**	**7**
17-3010	**Drafters**	**7**
11-0000	**Management, business, and financial occupations**	**7**
19-2030	**Chemists and materials scientists**	**8**
17-2051	**Civil engineers**	**8**
15-1131	**Computer programmers**	**8**
17-2070	**Electrical and electronics engineers**	**8**
17-2141	**Mechanical engineers**	**8**
15-1134	**Web developers**	**8**
19-1010	**Agricultural and food scientists**	**9**
15-1143	**Computer network architects**	**9**
17-2081	**Environmental engineers**	**9**
17-2110	**Industrial engineers, including health and safety**	**9**
11-9121	**Natural sciences managers**	**9**
15-2090	**Miscellaneous mathematical science occupations**	**10**

What are the most difficult STEM occupations to fill? Community stakeholders who participated in the BERC survey ranked occupations from 1 to 10 by difficulty of filling jobs. A rank of one means an occupation is extremely easy to fill, and a rank of 10 means an occupation is extremely difficult to fill. BERC aggregated the results of the community stakeholders' rankings into a master list that provides an average ranking on the difficulty of filling each occupation. Provided on the previous page is a segment of the master list that illustrates those occupations that are the hardest to fill. For example, the hardest occupation to fill was miscellaneous mathematical science occupations (15-2090), with an average ranking of 10. The occupations that are difficult to fill are not restricted to any set of occupational codes but offer an assortment of occupational profiles.

What are the most difficult STEM-related occupations to fill? This list was obtained in the same manner as the previous list but with STEM-related occupations. The table below offers a picture of the most difficult STEM-related occupations to fill. Physicians and surgeons (29-1060) is the most difficult STEM-related occupation to fill, with speech-language pathologists (29-1127) coming in at a close second. All of the STEM-related occupations that are most difficult to fill come from the healthcare practitioners and technical occupations set of codes (29-0000).

STEM-Related Occupations by Difficulty of Filling

Occupational Code	Occupational Title	Difficulty of Filling
29-1031	Dietitians and nutritionists	6
29-1141	Registered nurses	6
29-2010	Clinical laboratory technologists and technicians	7
29-1051	Pharmacists	7
29-1127	Speech-language pathologists	8
29-1060	Physicians and surgeons	9

Tennessee STEM Exposure Index

Creating an index and updating it annually require timely data at the county level. When dealing with STEM workforce dynamics, measurement at the county level is a challenging issue. This report utilizes the limited existing data on STEM workforce dynamics to present a Tennessee STEM Exposure or Concentration Index by county.

The STEM Exposure Index includes six indicators:

- STEM jobs as percent of total county jobs
- STEM jobs as percent of Tennessee STEM jobs
- Average ACT math score
- Average ACT science score
- College-going rate

- Patents per 1,000 employees (2004-13)

The following table shows the weights of each indicator and the reason for inclusion. The procedure to calculate the final index includes three major steps: (1) calculating averages and standard deviations for each indicator, (2) normalizing each indicator using average and standard deviation scores, and (3) applying the weights to create a final index for each indicator.

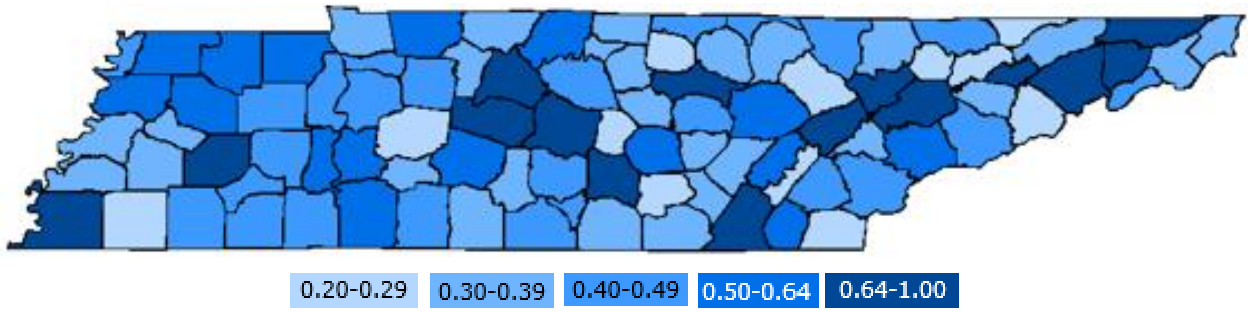
Indicators	Weights	Reason for Inclusion	Data Source
STEM jobs as percent of total county jobs	37.5%	County level STEM intensity	BERC calculations from ACS, ES202
STEM jobs as percent Tennessee STEM jobs	37.5%	Tennessee level STEM intensity	BERC calculations from ACS, ES202
Average ACT math score	5.0%	STEM readiness	Tennessee Department of Education
Average ACT science score	5.0%	STEM readiness	Tennessee Department of Education
College-going rate (%)	5.0%	College-bound	Driveto55.org
Patents per 1,000 employees (2004-13)	10.0%	Creativity	www.uspto.gov
	100.0%		

According to BERC calculations, Knox, Williamson, and Hamilton counties occupy the top three spots in the STEM Exposure Index. Other counties with high scores include Shelby, Davidson, Sullivan, Washington, Anderson, Madison, and Putnam. Rutherford County makes the top 15. A complete list of all counties and a map showing a regional perspective on the concentration are below.

Name	STEM Index	Rank
Knox	0.94	1
Williamson	0.94	2
Hamilton	0.90	3
Shelby	0.89	4
Davidson	0.87	5
Sullivan	0.86	6
Washington	0.84	7
Anderson	0.80	8
Madison	0.77	9
Putnam	0.75	10
Hamblen	0.70	11
Coffee	0.68	12
Greene	0.68	13
Rutherford	0.68	14
Roane	0.65	15

Name	STEM Index	Rank	Name	STEM Index	Rank
Knox	0.94	1	McNairy	0.42	48
Williamson	0.94	2	White	0.41	49
Hamilton	0.90	3	Benton	0.41	50
Shelby	0.89	4	Humphreys	0.41	51
Davidson	0.87	5	Sevier	0.41	52
Sullivan	0.86	6	Chester	0.40	53
Washington	0.84	7	Clay	0.40	54
Anderson	0.80	8	Bedford	0.40	55
Madison	0.77	9	Marshall	0.39	56
Putnam	0.75	10	Franklin	0.39	57
Hamblen	0.70	11	Campbell	0.39	58
Coffee	0.68	12	Lauderdale	0.39	59
Greene	0.68	13	Robertson	0.38	60
Rutherford	0.68	14	Lewis	0.38	61
Roane	0.65	15	Jefferson	0.38	62
Maury	0.63	16	Loudon	0.37	63
Dyer	0.63	17	Giles	0.37	64
Decatur	0.62	18	Dekalb	0.37	65
Bradley	0.59	19	Sequatchie	0.36	66
Blount	0.59	20	Smith	0.36	67
Gibson	0.58	21	Marion	0.36	68
Perry	0.58	22	Johnson	0.36	69
Henry	0.58	23	Hawkins	0.36	70
Weakley	0.57	24	Tipton	0.35	71
Wayne	0.55	25	Crockett	0.35	72
Cumberland	0.53	26	Trousdale	0.34	73
Sumner	0.53	27	Overton	0.34	74
Obion	0.53	28	Stewart	0.33	75
Rhea	0.52	29	Van Buren	0.32	76
Warren	0.50	30	Fentress	0.32	77
Montgomery	0.50	31	Bledsoe	0.31	78
Carroll	0.48	32	Macon	0.31	79
McMinn	0.48	33	Cheatham	0.31	80
Pickett	0.47	34	Haywood	0.31	81
Hardin	0.47	35	Carter	0.30	82
Claiborne	0.47	36	Cocke	0.29	83
Scott	0.46	37	Hancock	0.28	84
Hardeman	0.46	38	Grundy	0.28	85
Henderson	0.46	39	Grainger	0.28	86
Houston	0.45	40	Meigs	0.27	87
Dickson	0.45	41	Polk	0.26	88
Lake	0.45	42	Hickman	0.26	89
Wilson	0.44	43	Fayette	0.26	90
Monroe	0.44	44	Morgan	0.25	91
Unicoi	0.43	45	Moore	0.25	92
Lincoln	0.42	46	Jackson	0.25	93
Lawrence	0.42	47	Cannon	0.23	94
			Union	0.22	95

STEM Exposure Index by County



"This report clearly identifies the impact of the TN STEM Challenge. Tennessee's STEM workforce challenge is real and immediate. The potential for expanded growth in STEM businesses and industry in the state is strong, but Tennessee's current capacity to meet the highly skilled STEM workforce needs to support that growth is seriously underdeveloped. STEM businesses and industry and STEM-related occupations can play a pivotal role in creating a much-improved economic future for Tennessee and Tennesseans. But that future calls for aggressive action to bring business and industry sector pipeline needs in alignment with an educational pipeline that can meet those needs. The facts are clear: Increasing Tennessee's STEM workforce to the U.S. average alone would mean an additional 36,000 STEM jobs in Tennessee, and more importantly, would add $1.823 billion in wages and salaries to Tennessee's economy over the years. The question is: Can we afford not to meet the TN STEM Challenge?"

—Faye Johnson, Mind2Marketplace board member and assistant to the provost for special initiatives at Middle Tennessee State University

Chapter 8

Conclusion

This is the first report highlighting critical challenges facing the STEM workforce in Tennessee. Community stakeholders provided a detailed assessment of STEM supply, STEM pipeline, infrastructure, the role of government, and challenges to businesses. Based on these reviews as well as the state-level assessment of STEM indicators, this report draws the following conclusions:

- *Characteristics of STEM workforce.* Tennessee's STEM workforce is not competitive, characterized by an oversupply of low-skilled STEM workers compared with the nation.
- *STEM workforce supply and demand.* Demand for STEM workers outstrips the STEM supply with an average supply-to-demand ratio of 0.60, suggesting Tennessee either will fill those positions with people without a STEM degree or hire people from other regions.
- *Community stakeholders on STEM workforce dynamics.* Nearly three in four community stakeholders BERC surveyed indicated the STEM workforce challenge for Tennessee is real and involves not only parents and children but also the STEM industry itself, educators, and government. The efforts in this area are fragmented without clear direction from industry, higher education, or government.

Addressing the STEM workforce challenge is critically important for Tennessee for two major reasons:

- *Building the capacity for innovation and creativity.* A STEM workforce is highly educated relative to all other occupations in an economy. For Tennessee, the advanced manufacturing and healthcare industries have become major drivers of economic growth. To build sustainable economic growth, Tennessee should build the capacity of its workforce.
- *Fueling the economy with additional household income.* Addressing the low-skill problem and moving Tennessee's STEM concentration to the national level alone would create an economic impact of nearly $4.5 billion and create an additional 16,000 new jobs.

These benefits are associated with only a small fraction of the significant societal benefits that may be created by addressing the multiple and complex STEM workforce challenges discussed in this report. For example, creating business efficiency through increasing the capacity of the STEM workforce is not quantified in this report.

> *"Mind2Marketplace exists to bring the brightest and best ideas in middle Tennessee to reality. We strategically link people and organizations to bring innovation and technology to the marketplace. M2M's interest in the STEM dynamics study was to endeavor to quantify the people and organizations that are ready or needed to meet supply demands and to clearly identify the nature of these emerging demands. Dr. Arik's study achieves this objective. Our hope is that the results may prove instructive for how we can work together to achieve a more harmonized balance between the workforce and the companies that meet these demands, while creating increasingly more fertile ground for germinating even better and brighter ideas throughout and beyond the M2M footprint."*
>
> —Brian Robertson, Mind2Marketplace board chair and chief information officer for Rutherford County government

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Appendix

Survey Administration

In order to administer the business survey, BERC performed the following tasks. First, the number of STEM and STEM-related occupations were derived from the 2010 Standard Occupational Classification (SOC) manual and cross-referenced with Tennessee industry employment data from the American Community Survey. Then, this matrix was used to estimate the number of STEM and STEM-related jobs in Tennessee. Next, the sum of the number of STEM and STEM-related employees in each industry was divided by the total number of STEM employees in Tennessee to determine the distribution of STEM occupations across Tennessee's industries. Using this distribution, BERC targeted the industries with the highest percentages of STEM occupations. The companies that received the survey were pulled at random from a list of companies matching BERC's industry search parameters in ReferenceUSA, a business database. BERC made sure that the random assortment of companies was an accurate reflection of business size and location. BERC also targeted several economic development officials, mayors, and schools for participation in the survey. After the design of the survey was complete, BERC mailed each potential respondent a letter describing the study and the survey process. As a result, 210 respondents from all nine regions of Tennessee participated in the survey.

Selecting STEM Occupations

BERC selected STEM occupations according to the U.S. Census Bureau's classification. The Census Bureau's classifications are based on the 2010 SOC manual. According to the listing, there are 63 specific STEM occupations and 35 STEM-related occupations. These two groups are displayed in the table below.

STEM Occupations		
Occupations	Census Code	SOC Code
Management, Business, and Financial Occupations:	***0010-0950***	***11-0000 - 13-0000***
Computer and information systems managers	0110	11-3021
Architectural and engineering managers	0300	11-9041
Natural sciences managers	0360	11-9121
Computer and mathematical occupations:	***1000-1240***	***15-0000***
Computer and information research scientists	1005	15-1111
Computer systems analysts	1006	15-1121
Information security analysts	1007	15-1122
Computer programmers	1010	15-1131
Software developers, applications and systems software	1020	15-113X
Web developers	1030	15-1134
Computer support specialists	1050	15-1150
Database administrators	1060	15-1141
Network and computer systems administrators	1105	15-1142
Computer network architects	1106	15-1143
Computer occupations, all other	1107	15-1199
Actuaries	1200	15-2011
Mathematicians	1210	15-2021
Operations research analysts	1220	15-2031
Statisticians	1230	15-2041
Miscellaneous mathematical science occupations	1240	15-2090
Architecture and Engineering Occupations:	***1300-1560***	***17-0000***
Surveyors, cartographers, and photogrammetrists	1310	17-1020
Aerospace engineers	1320	17-2011
Agricultural engineers	1330	17-2021
Biomedical engineers	1340	17-2031
Chemical engineers	1350	17-2041
Civil engineers	1360	17-2051
Computer hardware engineers	1400	17-2061
Electrical and electronics engineers	1410	17-2070
Environmental engineers	1420	17-2081
Industrial engineers, including health and safety	1430	17-2110
Marine engineers and naval architects	1440	17-2121
Materials engineers	1450	17-2131
Mechanical engineers	1460	17-2141
Mining and geological engineers, including mining safety engineers	1500	17-2151
Nuclear engineers	1510	17-2161
Petroleum engineers	1520	17-2171
Engineers, all other	1530	17-2199
Drafters	1540	17-3010
Engineering technicians, except drafters	1550	17-3020
Surveying and mapping technicians	1560	17-3031

STEM Occupations (Continued)		
Occupations	Census Code	SOC Code
Life, Physical, and Social Science Occupations:	***1600-1965***	***19-0000***
Agricultural and food scientists	1600	19-1010
Biological scientists	1610	19-1020
Conservation scientists and foresters	1640	19-1030
Medical scientists	1650	19-1040
Life scientists, all other	1660	19-1099
Astronomers and physicists	1700	19-2010
Atmospheric and space scientists	1710	19-2021
Chemists and materials scientists	1720	19-2030
Environmental scientists and geoscientists	1740	19-2040
Physical scientists, all other	1760	19-2099
Economists	1800	19-3011
Survey researchers	1815	19-3022
Psychologists	1820	19-3030
Sociologists	1830	19-3041
Urban and regional planners	1840	19-3051
Miscellaneous social scientists and related workers	1860	19-3090
Agricultural and food science technicians	1900	19-4011
Biological technicians	1910	19-4021
Chemical technicians	1920	19-4031
Geological and petroleum technicians	1930	19-4041
Nuclear technicians	1940	19-4051
Social science research assistants	1950	19-4061
Miscellaneous life, physical, and social science technicians	1965	19-4090
Sales and Related Occupations:	***4700-4965***	***41-0000***
Sales engineers	4930	41-9031

STEM-Related Occupations		
Occupations	Census Code	SOC Code
Management, Business, and Financial Occupations:	***0010-0950***	***11-0000 - 13-0000***
Medical and health services managers	0350	11-9111
Architecture and Engineering Occupations:	***1300-1560***	***17-0000***
Architects, except naval	1300	17-1010
Healthcare Practitioners and Technical Occupations:	***3000-3540***	***29-0000***
Chiropractors	3000	29-1011
Dentists	3010	29-1020
Dietitians and nutritionists	3030	29-1031
Optometrists	3040	29-1041
Pharmacists	3050	29-1051
Physicians and surgeons	3060	29-1060
Physician assistants	3110	29-1071
Podiatrists	3120	29-1081
Audiologists	3140	29-1181
Occupational therapists	3150	29-1122
Physical therapists	3160	29-1123
Radiation therapists	3200	29-1124
Recreational therapists	3210	29-1125
Respiratory therapists	3220	29-1126
Speech-language pathologists	3230	29-1127
Exercise physiologists	3235	29-1128
Therapists, all other	3245	29-1129
Veterinarians	3250	29-1131
Registered nurses	3255	29-1141
Nurse anesthetists	3256	29-1151
Nurse midwives	3257	29-1161
Nurse practitioners	3258	29-1171
Health diagnosing and treating practitioners, all other	3260	29-1199
Clinical laboratory technologists and technicians	3300	29-2010
Dental hygienists	3310	29-2021
Diagnostic related technologists and technicians	3320	29-2030
Emergency medical technicians and paramedics	3400	29-2041
Health practitioner support technologists and technicians	3420	29-2050
Licensed practical and licensed vocational nurses	3500	29-2061
Medical records and health information technicians	3510	29-2071
Opticians, dispensing	3520	29-2081
Miscellaneous health technologists and technicians	3535	29-2090
Other healthcare practitioners and technical occupations	3540	29-9000