The Roles Parents, Educators, Industry, Community, and Government Play in Growing and Sustaining the STEM Workforce

Sam Zaza
Middle Tennessee State University

Amy Harris
Middle Tennessee State University

Murat Arik
Middle Tennessee State University

Patrick Geho
Middle Tennessee State University

This study was conducted to shed light on the perspectives of business leaders regarding the roles that various stakeholder groups (parents, educators and schools, industry and community partners, and government) should play in establishing and maintaining the supply of skilled STEM workers. A field survey methodology was employed to survey over 1,000 business executives and managers located throughout the southeastern United States. Their responses to open-ended survey questions were analyzed using textual analysis with topic modeling to reveal probabilistic thematic coverage, explore factors that may lead to more STEM-capable graduates, and ultimately a sustained STEM workforce. Results indicate that business leaders envision roles for all key stakeholder groups and that finding a successful solution will require interaction among the stakeholder groups if we are to be successful in creating a sustained pipeline of STEM talent.

Keywords: STEM, Parents, Educators, Industry, Community, Government

INTRODUCTION

It is widely known that the United States (US) suffers from a shortage of science, technology, engineering, and mathematics (STEM) workers and that the shortage is only anticipated to grow in the near future.

Economic projections point to a need for approximately one million more STEM professionals than the U.S. will produce at the current rate over the next decade if the country is to retain its historical preeminence in science and technology. (President's Council of Advisors on Science and Technology, 2012).[1]

The reasons for the shortage are two-fold. First, the number of STEM jobs is increasing. STEM employment grew at a rate just shy of 25% from 2005 to 2015, compared to only 4% for non-STEM employment (Noonan, 2017). The U.S. Bureau of Labor Statistics (BLS, 2017) reports an expected 8.9% growth rate for key occupations in STEM fields from 2014-2024, compared to a 6.4% growth rate for non-STEM occupations. Second, the US is not producing enough STEM workers to meet the growing demand. A recent report from the Bill and Melinda Gates foundation indicated that U.S. businesses do not have – and cannot find – the STEM talent they need to stay competitive.

While a plethora of initiatives have been introduced to increase STEM participation (e.g., Dillon et al., 2016; Exter & Lehman, 2016), the lack of a sustained, skilled STEM workforce within the U.S. remains a significant problem. Research suggests the US is losing potential STEM workers at all stages of their education. The US Department of Education (USDE) recently reported that only 24% of eighth-graders attending a school that offered Algebra 1 took the course (USDE, 2018). Considering that students with a solid math foundation may be more likely to pursue STEM courses in high school and choose a STEM-related major should the pursue post-secondary education (Moreno, Tharp, Vogt, Newell, & Burnett, 2016), this low enrollment number suggests a substantial "leak" in the STEM pipeline early in the education process. For those students who pursue a STEM field beyond high school, retention and success remain a challenge (Winberg, Adendorff, Bozalek, Conan, et al., 2019). Even obtaining a post-secondary STEM degree does not guarantee that an individual will pursue or remain in a STEM career. The U.S. Census Bureau reported that 74% of those who have a bachelor's degree in a STEM major are not employed in STEM occupations (Salzman, Kuehn, & Lowell, 2013; US Census Bureau, 2014). Taken all together, there is ample evidence of the "leaks" in the STEM workforce.

Addressing both the existing and projected shortages in STEM workers will require thoughtful, coordinated intervention from multiple stakeholder groups at all points along the STEM education pipeline. The "learning ecosystem" proposes that there are various facets in an individual's life that impact decisions around pursuing STEM education, including family, school, community, and government (Krishnamurthi et al., 2014). This study was conducted to shed light on the perspectives of business management personnel located throughout the southeast US regarding the roles that these various stakeholder groups should play in sustaining the supply of skilled STEM workers. Specifically, our research questions are:

RQ1: *What role should parents play in sustaining the supply of STEM workers?*

RQ2: *What role should educators play in sustaining the supply of STEM workers?*

RQ3: *What role should business, industry, and other community partners play in sustaining the supply of STEM workers?*

RQ4: *What role should government play in sustaining the supply of STEM workers?*

To address these research questions, we provide a review of the STEM literature around each stakeholder group. We then provide the methodological details of the study and report the findings. The findings are discussed and the key take-aways for each of the stakeholder groups are provided.

BACKGROUND

In this section, we explore four stakeholder groups that may influence the development of a sustained STEM-capable workforce: parents, educators/schools, community/industry, and government.

Parents

Parents have been shown to have considerable influence on their children's educational and career decisions. Parents are important in the development of their children's self-efficacy, which is their belief

in their ability to achieve goals in various components of life (Gist & Mitchell, 1992). Parental support of the individual is thought to be an especially important factor in the decision to enter or remain in STEM (*Harackiewicz, Rozek, Hulleman, & Hyde, 2012*; *Rozek, Svoboda, Harackiewicz, Hulleman, & Hyde, 2017; Mangu, Lee, Middleton & Nelson, 2015*). Due to their proximity to their children, parents are found to be among the primary influencers of STEM knowledge and career acquisition (STEMconnector, 2018). Parents often establish expectations for their children that impact their pursuit of STEM knowledge (*Halim, Rahman, Zamri, & Mohtar, 2018;* Yamamoto & Holloway, 2010, Lee & Shute, 2010). Research has shown that parental engagement shapes children's values and motivation related to STEM fields (*Harackiewicz et al., 2012;* Lee & Shute, 2010; *Nugent, Barker, Welch, Grandgenett, Wu, & Nelson, 2015)*.

Educators / Schools

Educators (and schools) are pivotal in continuing to feed the STEM pipeline by inspiring and educating prospective STEM workers. The K-12 learning years are of critical importance in the development of a student's STEM capacity and perception of its utility, enhancing or hindering the desire and ability for an individual to pursue further STEM study in higher education (Nugent et al., 2015; Mangu et al., 2015). During the K-12 education years, students gain knowledge of an array of subjects, including those related to STEM. However, for much of the US, there are challenges associated with finding qualified STEM teachers, which prevents many students from being exposed to quality STEM education (Milgrom-Elcott, 2019).

In higher education, even though enrollment in STEM disciplines has been increasing, the retention and success of STEM undergraduate students remain a challenge (Winberg et al., 2019). Researchers have proposed that if STEM majors are "to retain students, there needs to be a shift towards teaching in more enriching and interesting ways" (Pollard, Hains-Wesson, & Young, 2017). Effective undergraduate STEM pedagogies have been developed but are yet to be implemented on a larger scale. Strategies have been developed to help educators in higher education consider changing the way they teach STEM subjects and encourage them to use teaching practices proven to be effective in engaging students in STEM education (Borrego & Henderson, 2014).

Community and Industry

Community and industry stakeholders are engaging in a wide variety of activities to address leakages in the STEM talent pipeline. These activities include pledging large sums of money to fund K-12 education programs (Sytch, 2017), providing scholarships and grants to college students (21CF and…, 2017), participating in community - school partnerships and internship programs (*Krishnamurthi et al.,* 2014; 21CF and…, 2017), and introducing recruiting incentives such as hiring bonuses, loan forgiveness or repayment incentives, and pay/benefit incentives (*Graf et al., 2018*). Acknowledging the importance of exposing students to STEM concepts through activity at a younger age, some retailers (Longwell, 2018) are also offering a monthly subscription program for toys and games that incorporate STEM components.

Government

The government, at both the federal and state levels, plays an important role in allocating funds and creating programs that positively impact STEM education. The two most recent presidential administrations established programs designed to address the decline in science and technology activities in the US and to train and retain excellent STEM teachers (Curran, 2019; Enriching America's…, 2019). *T*he US government has also tailored programs to educate parents about the importance of STEM career choices (*Halim et al., 2018*; *Harackiewicz et al., 2012*).

Given the disparate research on the various stakeholder groups that affect the ability of the US to sustain a skilled STEM workforce, this study sought the recommendations of business professionals about the actions needed to sustain a skilled STEM pipeline across the Tennessee Valley Corridor states.

RESEARCH METHOD

To address our research questions, we collected data over a three-month period using Qualtrics Panels. All respondents were business professionals living in the Tennessee Valley Corridor (TVC) member states (Alabama, Kentucky, North Carolina, Tennessee, and Virginia). The TVC is an economic development organization that focuses on supporting federal science and technology missions. The main goals of the TVC are (1) to support and expand federal and state missions and investments in the Corridor; (2) to leverage the Corridor's growing science and technology assets for maximum new job creation and next-generation manufacturing in the region; and (3) to promote the Tennessee Valley Corridor as one of the premier science and technology regions in the U.S. Due to the TVC states' focus on science and technology, they were deemed a good candidate for study of perceived stakeholder roles regarding the development of a sustained supply of skilled STEM workers. In all, 1,011 respondents (e.g., President, CEO/CFO, and manager) completed the survey (150-200 respondents from each member state). Table 1 shows the breakdown of respondents by their businesses' industry classification. The majority of businesses have 250 or more employees.

The survey included open-ended questions seeking business leaders' insights on the role of key stakeholders in sustaining the STEM workforce. The following four questions were included in the study to address our research questions:

- *What role should parents play in making STEM educational choices for children?*
- *What role should educators play?*
- *What are the potential ways to engage business, industry, and other community partners to advance STEM?*
- *If there is a role for the government in promoting STEM, what role should it play?*

TABLE 1
INDUSTRY CLASSIFICATION

Industry Classification	Count	Percentage
Automotive	47	4.65
Advanced Manufacturing	128	12.66
Chamber/Economic Development	2	0.2
Chemical Products and Plastics	20	1.98
Education	49	4.84
Energy Technologies	42	4.15
Healthcare	173	17.11
Professional and Business Services	396	39.17
State and Local Government	32	3.17
Transportation, Logistics, and Distribution Services	36	3.56
Other (please specify)	86	8.51
Total	1011	100

In the first step, data were preprocessed and readied for analysis. This preprocessing included cleaning the data by removing incomplete records. For the second step, we extracted the thematic

coverage found in the data collected from the respondents on the four questions. We used textual analysis with topic modeling to reveal the probabilistic thematic coverage, explore factors that may lead to more STEM-capable graduates, and ultimately a sustained STEM workforce. We applied a cloud-based tool called MineMyText available at http://www.minemytext.com/. We used topic modeling, through MineMyText, to discover the topics conveyed by the unstructured texts/responses in a completely automated, data-driven manner. The web-based application searches for words that co-occur in similar contexts and places them into sets. Since these words tend to have similar meanings, the application interprets these sets as topics. Therefore, the tool has the capability of clustering unstructured texts into thematic categories. MineMyText uses the Latent Dirichlet Allocation (LDA) algorithm to discover these topics. Since LDA is an unsupervised machine learning algorithm, the resulting probabilistic topics discovered are purely data-driven from the texts imported to the web-based system.

Because topic modeling is an unsupervised technique, we can only specify the number of topics to be extracted a priori. Multiple iterations had to be applied to determine the most suitable number of topics to extract. Based on the criteria put forth by Bouma (2009) and Lau et al. (2014), we carried several iterations to the data to determine the most suitable number of topics to be extracted. For instance, the three-topic model for the parent stakeholder group yielded topic themes that were most pronounced and most distinguishable when compared to models with two-, four-, or six-topic models. Therefore, we deemed three topics most appropriate for the parent stakeholder group. For further information on topic modeling, please refer to the tutorial offered by Debortoli et al. (2016).

Before processing the data, we excluded all frequently used, uninformative words such as "N/A," "student," "stem", and "role". Words were reduced to their dictionary form. Table 2 depicts the topics identified for each stakeholder group, along with quotes and frequently used words. For example, the parent stakeholder group has three topics. Topic one is characterized by the words "learn", "interest", "career", "teach", and "choice". The listing of words, along with reading through the exemplary content (i.e., the relevant quotes associated with this topic provided by MineMyText) allows us to infer that the first topic discussed by our respondents, deals with encouraging children to explore STEM knowledge. Note, each topic is presented and discussed in detail in the next section.

RESULTS AND DISCUSSION

We started this research seeking insights from businesses about 1) the role of parents in STEM educational choices for children, 2) the role of educators in promoting STEM field, 3) the potential ways to engage business, industry, and other community partners to support promoting STEM field, and 4) the role of the government in promoting STEM field. Table 2 summarizes the results which are detailed next.

As shown in Table 2, we were able to identify three topic ideas aimed at each stakeholder group to increase the STEM pipeline sustainability. Each topic idea is detailed in the following section.

TABLE 2
TOPIC MODELING RESULTS

Topic ID	5 Most Frequently Used Words	Exemplary Content	Interpretation of the Topic
Parent			
1	Learn, interest, career, teach, choice	I think they should partner with teachers and be not only motivational support for kids but also willing to be students themselves.	Learn about STEM
2	Support, education, involve, opportunity, activity	They should encourage children to explore their interest in these areas not just at school, but with projects and things at home. Make time and space for their children to explore ideas.	Encourage children to explore STEM knowledge
3	Encourage, field, encouragement, provide, school	Parents should assist their children in exploring higher education paths that will ensure employment in a long term viable field.	Encourage children to explore STEM as an educational and career path
Educator			
1	Interest, activity, skill, future, science	Often, teachers themselves were never deeply educated in STEM and that impacts students' exposure to STEM.	Secure quality K-12 STEM teachers
2	Encourage, education, support, information, school	Educators should develop fun and engaging STEM-related after school programs. They should also take special care to ensure young girls are encouraged in STEM education.	Inspire interest in STEM knowledge
3	Learn, opportunity, career, job, option	Recruit families as workers and local employers to attend career fairs or info sessions at schools to show employment opportunities to students, open classes to workforce-related credits and preparation for employment at local companies, coordinate internship opportunities with local employers.	Inspire interest in a STEM career

Source: Authors

TABLE 2
TOPIC MODELING RESULTS (CONTINUED)

Topic ID	5 Most Frequently Used Words	Exemplary Content	Interpretation of the Topic
Industry			
1	Incentive, education, support, advance, engage	Provide early intervention for children and provide support to adults who want to switch to a STEM career.	Develop partnerships with K-12 and higher education to raise awareness about STEM fields
2	Fund, train, internship, industry, awareness	Potential ways to engage business, industry, and other community partners to advance STEM include increasing awareness, training educators to transfer knowledge and skills to younger or newer generations of members of society.	Support educators gaining expertise in teaching STEM concepts
3	Job, work, show, advertise, benefit	Show them a profit. A defined profit in a specific time frame. A ROI they can grasp.	Inspire interest in pursuing a STEM career
Government			
1	Support, awareness, job, grant, promote	Improving awareness of job availability and encourage work in the STEM field.	Support STEM graduates' transition to the workforce
2	Fund, financial, education, scholarship, pay	Programs for young students to experience STEM related projects in a summer camp environment funded by government funds.	Encourage interest in STEM knowledge
3	Education, incentives, school, train	Changing the way STEM subjects are taught in public school.	Support educators in engaging in quality teaching

Source: Authors

Recommendations for Parents

The first topic that emerged focused on the role of parents we labeled "**Learn about STEM**". The respondents indicated that parents need to educate themselves about STEM subjects and career path options in order to help their children be better informed. In addition, parents can partner with teachers because children do not learn only at school. As one responded stated:

> *Parents should see them [STEM] as viable career paths. Education geared towards parents should help them see that there are other career paths from doctors and lawyers.*

While another responded commented:

> *I think they should partner with teachers and be not only motivational support for kids but also willing to be students themselves. I have found that learning along with my kids has been a wonderful experience for everyone.*

We labeled the second topic that emerged focused on the role of parents "**Encourage children to explore STEM knowledge**". The respondents commented that parents, as the first line of contact with students, play a major role in directing their children into the chosen program of study even at the early stages in school. Parents are encouraged to recognize and build the natural abilities of their children and help them develop their talents. In addition, parents should encourage their children to take advantage of any learning experience they can embrace including participation in extra-curricular academic programs such as STEM club programs and camps. Parents play a major role in a child's life and impact their children's attitude and ability to engage in STEM education. When parents engage in STEM-related activities and show positivity, children assign a higher value to STEM subjects (Simpkins et al., 2015). As one of the respondents mentioned:

> *[Parents should] encourage their children by buying STEM-related materials for them. It is important they encourage their children to participate in STEM-related activities regularly and take Science and Math classes and extracurriculars… Parents should provide children opportunities to participate in STEM extracurriculars as they currently do for sports.*

We labeled the third topic that emerged focused on the role of parents "**Encourage children to explore STEM as an educational and career path**". Encouraging children to be involved in STEM and engaging in STEM-related activities at school and at home is the foundational building block. As a next step, parents may give their children information about STEM jobs and get them acquainted with potential occupation choices and salaries. Parents should see STEM career paths as viable and worthy to pursue just like careers in medicine and law. As one of the respondents stated:

> *Parents should assist their children in exploring higher education paths in STEM that will ensure employment in a long-term viable field, far too many parents allow their kids to spend $100k on a [some other] degree and then they can't make a living… [Parents should] educate their children on how important STEM-related jobs and opportunities are now more important than ever. And should encourage them to further explore classes, education in these careers.*

Recommendations for Educators

The first topic that emerged we labeled "**Secure quality K-12 STEM teachers**". Respondents indicated that teaching STEM goes beyond the textbook and lecture method of teaching. To ensure students' inspiration and engagement, teachers need to know STEM concepts. We must be willing to invest in preparing excellent STEM teachers to ensure that what is taught in STEM programs is effectively presented. As one of the respondents mentioned:

> *The educational system has fallen so low it is like why even send your child to school. There are teachers that don't even understand what they are teaching themselves and if the teachers' guide w/ the answers is taken away they are more lost than the students they are so-called teaching. School is too focused on other things, teachers are more concerned w/ pay than they are giving children quality education. There is no foundation for STEM education.*

While another respondent mentioned:

> *[Schools] need to invest and train STEM teachers… [Teachers] were never deeply educated in STEM and that impacts students' exposure to STEM. [Schools] should work to make STEM programs [for students] and training [for educators] available at all levels and social stages.*

For students to have access to quality STEM programs, educators need to be trained to deliver quality instruction, not just at the college level but early on. As one of our respondents stated:

> *Better screening and training for educators to ensure all students are afforded the same opportunities, and assisting [educators] in encouraging STEM courses in schools.*

We labeled the second topic that emerged focused on the role of educators "**Inspire interest in STEM knowledge".** If the foundation is equipping educators to teach STEM concepts, the next building block is knowing how to weave STEM content into classrooms. Teachers need to shed light on the connections between STEM content and real-life applications and incorporate them into everyday lessons for the students. To become genuinely interested and engaged in STEM subjects, students need worthwhile, hands-on experiences that relate concepts to real-world issues and topics that stimulate their critical thinking. As one of the respondents stated:

> *[Educators] need to make classes interesting and incorporate STEM into early elementary classes in every subject. Within the classroom, it is the responsibility of the educator to cover all the necessary material and how what they are learning will be applied in REAL life circumstances.*

While another respondent commented:

> *[Educators] play an integral role in the process of student learning, because they act as a knowledgeable medium between the student and subject matter. [Educators should] provide more opportunities for the curious and passionate child to pursue STEM-related activities. For example, coding clubs and other after-school activities. Also, the classroom should be a place for hands-on learning, not just lecturing.*

We labeled the third topic that emerged focused on the role of educators "**Inspire interest in a STEM career".** Interest can be established not only through programs and activities but also through the attractiveness of potential STEM careers. Educators should provide appropriate support and understand how to promote STEM careers, to show the options in the field, and stress the importance of STEM in the global arena. As one of the respondents stated:

> *[Educators] need to take an active role in educating students on the top careers in STEM education, emphasizing the importance of each and how they relate to our country's strength and prominence.*

While another respondent stated:

> *[Educators should] encourage both male and female to join the mathematics and sciences as career fields. [Educators need to] realize [that] there are knowledge and a gender gap and stop perpetuating both.*

Recommendations for Industry

The first topic that emerged focused on the role of the industry we labeled "**Develop partnerships with K-12 and higher education to raise awareness about STEM**". In the US, access to STEM programs is most commonly provided by schools and communities. The respondents indicated that businesses need to participate in STEM outreach programs for both groups. For example, businesses can send employees to talk to schools (K-12 and post-secondary), to help raise awareness about the importance of STEM and its relevance to today's innovation needs. As one of the respondents stated:

There is not enough coordination between potential employers in the STEM fields and teachers in the STEM fields. My company reaches out to grade school students with open houses and intro to code classes. More [STEM] companies should be reaching out to area grade schools to show kids how many different ways they can sell their labor when they grow up. When I was a kid, I didn't know there was a project manager or a user interface designer job.

Another respondent commented:

[Industry needs to provide] high school support programs to drive interest or gain interest in youth taking a STEM route. Many school districts can't afford the equipment needed and it should be provided through business/industry relationships, not from the government. In my community, there is a local museum which hosts a day of STEM-related activities for local children. I think that increasing awareness and encouraging the youth to become involved in STEM is an excellent way to advance STEM.

In addition, partnering with schools by funding STEM programs at the post-secondary education level will enable students to understand STEM careers as they use machines, equipment, tools, and techniques in the laboratories that are similar to those used on the job. Furthermore, businesses can create scholarship programs for specific fields and/or positions needed in STEM. As one of the respondents mentioned:

In Richmond, VA there is a school primarily for coding sponsored by private business/industry, but it operates in conjunction with local county schedules. If this model was promoted for other areas of STEM, I see a huge increase in the number of students flowing into the STEM pipeline. The school is more of an open model with small classes and operates to focus on coding. The students are self-directed with teachers there as a guide. Less time is wasted. Students are more engaged. More productive time can be spent on STEM.

We labeled the second topic that emerged focused on the role of industry "**Support educators gaining expertise in teaching STEM subjects"**. At the post-secondary education level, STEM employers can help teachers prepare lectures by proposing the most relevant skills/concepts needed in the current STEM job market. Schools can tailor degree paths to STEM careers based on the feedback from STEM employers. As a respondent stated,

Non-profits [organizations] intend to spread STEM awareness, such as educating teachers and parents in STEM—since one reason kids lack awareness is due to the lack of teacher and parent training. Advertising the programs to employers and education institutions [that help in] tailoring degree paths to specific careers… [Industry needs to work on] having teachers strong enough to provide the classroom training in math disciplines as well as advanced science and chemistry. Training teachers on the latest trends.

While another respondent commented:

Potential ways to engage business, industry, and other community partners to advance STEM include increasing awareness, training educators to transfer knowledge and skills to younger or newer generations of members of society, and providing scholarships if possible and internship opportunities to students and young adults looking to get into the field.

At the K-12 education level, businesses indicated that efforts should be put forth to help educators teach STEM subjects. As one of the respondents stated:

> *Positive change in the quality of our workforce comes from STEM education. Partnerships with businesses, nonprofit organizations, and industries are very important in STEM education. Business partners can accelerate the progression of STEM talent development by collaborating with educators, and provide solid teachers as well as innovative curriculum and programs for students to choose from and participate in. There are many benefits of engaging in STEM education partnerships.*

We labeled the third topic that emerged related to the role of industry "**Inspire interest in pursuing a STEM career".** One way businesses can partner with post-secondary education institutions is by offering internship opportunities. These opportunities can provide work experience for students to learn about STEM jobs. Internships provide students exposure to the workplace in a STEM area of interest and provide a sense of the field and the specific type of work they would do if they pursued a STEM career path. As one of the respondents stated:

> *More info sessions for students, families, and educators to see and hear from real local employers on the practical job training, day to day work and operations, and how this serves their community. Offering internships to encourage students to work locally in a high skilled [STEM] job with good pay and benefits.*

The industry should put effort into transitioning skilled STEM graduates into the workforce. As one of the respondents stated:

> *Encouraging students to get excited about studies by bringing to light actual careers and even have presentations from people currently in the various fields to engage their students directly. Students would have exciting projects and be able to interact with people who are innovators in STEM programs.*

While another respondent commented:

> *[Industry should] offer programs or scholarships that build bridges from training to job placement within the industry. [Industry should engage in] campaigns to engage parents, teachers, employers in the career fields.*

Recommendations for Government

The first theme that emerged focused on the role of government we labeled **"Support STEM graduates' transition to the workforce"**. Respondents did not specify whether the recommendations they offered related to the federal or state level. However, respondents urged the government to take an active role in transitioning STEM graduates to the workforce. As one the responded stated:

> *[The government] should know the importance of the field for the future. Job opportunities specific to recent graduates of STEM programs [should be available] … [Students need] job training programs [to enter the STEM workforce] … [and] keep and retrain older employees.*

While another respondent commented:

The government might look to promote job creation. [Post job vacancy] ads on social media… [Government should] help to make more jobs available for the students to set as their career in life.

We labeled the second theme that emerged focused on the role of government **"Encourage interest in STEM knowledge"**. That support could be in the form of financial incentives for stakeholders. For students, incentives might include scholarships, lower tuition fees, lower interest rates on student loans, and free programs as one of our respondents mentioned:

The government could provide funding and incentive programs for schools that develop unique STEM programs and scholarships or incentives for STEM students, especially females… scholarships for women in STEM study [should be provided].

While another respondent commented:

Better state tuition rates for STEM, and lower student loan rates or waivers for STEM education and funding for low income and middle-class students to be able to afford costs of STEM educations… Programs for young students to experience STEM-related projects in a summer camp environment funded by government funds.

For educators, our respondents stated that the U.S. government needs to incentivize educators to teach STEM concepts and curriculum by, for example, increasing pay for STEM teachers or giving them the technologies needed to support their teaching. As one of the respondents mentioned:

More funding for school programs for learning STEM-related job skills… Funding for new technologies. Also, [the government can propose] to set a higher pay rate for teachers and financial incentives based on their ability to teach STEM.

For the industry/community, the respondents felt that support could be in the form of tax breaks. As one of the respondents commented:

[The government] can offer tax benefits for employers who provide support to schools or women's organizations to promote STEM. [The government] can offer a tax break for companies hiring STEM graduates.

While another respondent suggested:

Rather than just give tax cuts to corporations, make them earn tax cuts by helping people in the workforce advance... [Government needs to] propose tax breaks for companies who hire more graduates from STEM fields. Through government programs maybe give a tax break to companies who send employees to take one or more classes per quarter.

We labeled the third theme that emerged focused on the role of government **"Support STEM educators engaging in quality teaching"**. Government focus should be on building a strong foundation for STEM education. Students need high-quality STEM programs that prepare them to join and compete in the STEM workforce of the future. As one of our respondents mentioned:

Changing the way STEM subjects are taught in public school. Encourage more technical training vs. requiring unnecessary courses/credits to qualify for a degree. Fewer courses can reduce cost… Making higher education affordable and equal access to quality grade school education.

IMPLICATIONS

Our research has multiple implications for the TVC states. As we saw from the findings, key stakeholders play an important role in supporting a sustainable skilled STEM workforce within the US. The key ingredient for the overall effectiveness of these recommendations will be leveraging the synergies between these groups.

For parents, an effective tool is to engage their children with STEM-related activities that provide a hands-on experience. Various companies have created interactive toys that aim to foster STEM understanding and interests. One of the most recognizable toy brands is LEGO. The LEGO company has recently released the LEGO Education WeDo 2.0, which "combines the LEGO brick, classroom-friendly software, engaging standards-based projects, and a discovery-based approach" (WeDo 2.0 . . .). Further, if parents desire, they can do a simple search for STEM toys online. For example, Amazon, a popular e-commerce website, currently lists over 1,000 potential choices for parents and their children (STEM Toys…).

Experiential learning does not necessarily have to be limited to hands-on approaches and does not need to entail purchasing STEM toys for their child. There are various other activities to expose children to STEM subjects, such as watching STEM-related TV shows with their children. Common Sense Media, a media rating platform, compiles lists of popular STEM-related TV programs, particularly those that emphasize science that engages children from as early as three years of age (Best Science Shows…). Some of the shows are easily recognizable, potentially shows parents themselves are familiar with, such as Bill Nye the Science Guy or Myth Busters. Simply enjoying the show with their child and even engaging in similar activities afterward may instill an interest in STEM which encourages them to enter the STEM pipeline at an early age. Parents simply exposing their children to prospective STEM careers paves the way for them to consider pursuing one.

To bring high-quality STEM learning to students, teachers need support such as professional development/training so they can master the skills needed to be effective teachers now and in the future. While there is more work to be done to make this information readily available/accessible, resources already exist that can be leveraged by educators. One such example is the Tennessee Valley Authority's (TVA) STEMready website. This website provides educators with "ready-made STEM project-based learning modules". It also provides a breakdown of activities by education level, detailing how to carry out the activity, the required materials, and contact information for local business partners to aid in better understanding the project and its greater impact (see https://www.tvastem.com/pbl/solar-energy/).

Universities typically have strong outreach initiatives designed to engage in STEM-related activities within the local community. Middle Tennessee State University (MTSU) and the University of Tennessee Knoxville (UTK) campuses have outreach programs in place to positively impact the STEM pipeline. MTSU's Tennessee STEM Education Center (TSEC) is engaged directly with the provision of STEM opportunities for students and teachers alike to go beyond the classroom by becoming engaged in influencing policy outcomes that impact K-12 STEM education. UTK's Institute of Agriculture has developed various programs designed to engage K-12 students in STEM-related activities. They have also developed the "AGirlCulture" program, which aims to address gender issues in the STEM workforce.

Educators can invite guest speakers to their classrooms from the STEM field to talk to students about career options. Also, schools host career fairs for students to get the opportunity to meet and network with potential employers from multiple industries. In addition, students will learn about job opportunities in these industries and will have a chance to explore these job options and speak with employers about what makes an ideal employee for those positions. Career fairs can draw students' attention and introduce them to alternative STEM career paths they might not have thought about previously.

For community and industry, getting governmental incentives such as tax credits for engaging in a STEM field and recruiting STEM graduates would play a role in enabling them to advance STEM. To raise awareness about STEM, industries in the Tennessee Valley area are partnering with schools to foster the desired skills required to enter the workforce following the completion of post-secondary education. Work-based learning (WBL) programs have been critical in fostering skillsets and bridging perceived

gaps between education and the workforce (Jackson, Hobson & Crowe, 2018). While this program is not limited to STEM, industries should seek to engage with students through programs such as this or to establish internship opportunities for STEM students.

To further support STEM, the industry can partner with the government to increase the number of STEM graduates. For instance, Nissan North America and the state of Tennessee partnered to open the Tennessee College of Applied Technology, which offers programs such as Boosting Engineering Science and Technology (BEST) Robotics competitions, Girls Raised in Tennessee Science (GRITS), the Lipscomb University/Nissan BisonBot Robotics Camp, and the Expanding Your Horizons (EYH) initiative hosted by MTSU (Nissan in the Community). Community resources can be invested in providing programs, such as Girls Raised in Tennessee Science, which target the youth, potentially sparking their interests and influencing them to pursue STEM degree fields in their post-secondary studies.

The government, at both the federal and state level, has many ways in which it can support STEM programs. The Tennessee STEM Innovation Network (TSIN) is the product of a partnership between the Tennessee Department of Education and Battelle, a non-profit science and technology company, to develop a network that assists in developing K-12 interest in STEM. This assistance is developed in many ways, including (1) programs designed to assist in promoting STEM awareness and implementing STEM education in rural areas, (2) providing programs that emphasize STEM professional development and enhance industry and school partnerships, and (3) providing opportunities for STEM engagement in the classroom.

Students need to afford to pursue a STEM degree. Another potential government action might be lowering student loan interest rates for those pursuing STEM degrees and/or providing additional grant and scholarship opportunities. The Department of Defense (DoD) developed the Information Assurance Scholarship Program (IASP)[2] that offers grants and scholarships to students who have demonstrated ability and aptitude for excelling in STEM fields in disciplines of importance to DoD (STEM Scholarships). This program serves as a tool to develop and retain well-educated military and DoD civilian personnel who support the Department's critical information technology management and infrastructure protection functions.

The government might also offer incentives to educators to teach STEM subjects by developing programs targeted to retain them. One such existing program is the Teacher Loan Forgiveness Program[3] which provides loan forgiveness to teachers who are willing to teach in a low-income school or educational service agency for five consecutive academic years (Teacher Loan Forgiveness). While this opportunity is available to teachers of all subjects, the highest amount of forgiveness, up to $17,500, is reserved for highly qualified full-time science and mathematics teachers who teach in secondary schools.

CONCLUSION

This study uncovered important insights from business leaders in five states located in the southeastern US. While the insights gleaned from the study are potentially generalizable to all regions of the country, future research should seek to explore the same questions in other geographic regions – or nationwide – to determine if the issues identified are consistent across the country. Other potential directions for future research include identifying the key success factors in interactions between the various stakeholder groups in order to achieve a sustainable STEM pipeline and investigating the extent to which these recommendations if implemented, would impact the economy.

We were able to shed the light on the recommendations from business executives and managers spanning multiple industries across five southeastern states on the roles parents, educators/community and industry, and government stakeholders should play in sustaining a skilled STEM-graduates workers pipeline. There was wide agreement that strong STEM education is a path to a successful career and that the need for STEM knowledge and skills will continue to grow in the future. Although the STEM pipeline remains “leaky”, our analysis suggests that business leaders think the key to plugging the leaks involves partnerships between parents, educators, industry, and government if we are to be successful.

ENDNOTES

1. President's Council of Advisors on Science and Technology, Engage to excel: producing one million additional college graduates with degrees in science, technology, engineering, and mathematics (Executive Office of the President of the United States, 2012).
2. https://dodstem.us/stem-programs/scholarships
3. https://studentaid.ed.gov/sa/repay-loans/forgiveness-cancellation/teacher

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