What CEOs Have to Say: Insights on the STEM Workforce

American Business Review
May 2020, Vol.23(1) 136 - 155

ISSN: 2689-8810 (Online)
ISSN: 0743-2348 (Print)

Sam Zaza[a], Kristie Abston[b], Murat Arik[c], Patrick Geho[d] and Victor Sanchez[e]

https://doi.org/10.37625/abr.23.1.136-155

ABSTRACT
Establishing and maintaining the supply of skilled STEM workers are issues that many businesses are currently facing. CEOs can provide unique perspectives on the roles of parents, educators and schools, industry and community partners, and government on this issue. To this end, a Qualtrics panel was used to survey 45 CEOs located in the state of Georgia in the southeastern United States. CEOs responded to open-ended questions that were later analyzed using topic modeling techniques to uncover the themes and the factors that have the potential to increase the number of STEM-capable graduates and, ultimately, a sustained STEM workforce. The results of this study indicate that CEOs perceive parents, educators and schools, industry and community partners, and government as key players who are recommended to interact, engage and collaborate to successfully create a sustained pipeline of STEM talent. Business leaders, university business programs, and business faculty should stay abreast of the factors affecting the supply and demand of STEM workers, and this paper adds value by reporting on CEO perspectives on this important problem.

KEYWORDS
STEM workforce, CEO insights, parents, educators ,schools ,government

INTRODUCTION

The United States (US) struggles with a shortage of science, technology, engineering, and mathematics (STEM) workers, and that shortage is projected to grow in the near future. Several business majors, such as information security, operations analysts, and business intelligence, are among the fastest-growing STEM occupations (USDOL, n.d.). As the president of the Advisors on Science and Technology Council stated, "Economic projections point to a need for approximately 1 million more STEM professionals than the US 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, para. 1). Many researchers and market analysts studied the reasons behind this shortage and identified two primary causes.

First, the job market is healthy, with low unemployment rates – 3.6% in February 2020 (USBLS, 2020), and the demand to fill STEM jobs is increasing. For example, STEM employment grew by 25% from 2005 to 2015, compared to only 4% for non-STEM employment (Noonan, 2017). The US Bureau of

[a] Middle Tennessee State University, sam.zaza@mtsu.edu
[b] Middle Tennessee State University, kristie.abston@mtsu.edu
[c] Middle Tennessee State University, murat.arik@mtsu.edu
[d] Middle Tennessee State University, pgeho@tsbdc.org
[e] Middle Tennessee State University, vms2j@mtmail.mtsu.edu

Corresponding Author:
Zaza (sam.zaza@mtsu.edu)

Labor Statistics (Noonan, 2017) projected an 8.9% growth rate for STEM occupations from 2014-2024 compared to 6.4% in non-STEM occupations.

Second, the US is not producing enough quality STEM workers to meet the growing demand. For instance, based on a report issued by Georgetown University, US businesses are struggling to find highly skilled workers to fill STEM jobs (Carnevale et al., 2011). Further, US manufacturers are offshoring, hiring STEM workers abroad (Carnevale et al., 2011).

It is undeniable that much effort has been employed to increase STEM participation (e.g., Dillon et al., 2016; Exter & Lehman, 2016). Yet, the lack of a sustained, skilled STEM workforce remains a problem. Existing literature highlights the loss of potential STEM workers at all stages of their education. For instance, at the elementary level, Algebra 1 is considered as a proxy for the probability of students choosing a STEM subject. In 2018, for schools offering Algebra 1, only 24% of eighth-graders attending a school took that course (USDE, 2018). Having this low percentage indicates a "leak" in the early stages of the educational process. Moreno et al. (2016) argued that students with a math background are the ones who are most likely to pursue STEM subjects during high school and even a STEM major later. Even with a strong math foundation, retaining college students in STEM-related majors is still a challenge (Winberg et al., 2018). The challenge persists for STEM graduates as to whether they will choose a STEM career or even remain in the STEM field as per the US Census Bureau (2014).

While we have solid rationale to support that "leaks" exist and are persistent throughout the educational and career process, directly affecting the STEM workforce, we recognize that some experts propose that there is no shortage in the STEM workforce (Camilli & Hira, 2019; Charette, 2013). A recent special issue in the Journal of Science Education and Technology (2019) reported on the STEM workforce and education (Camilli & Hira, 2019). Systems software developers was one profession reported as an example of having adequate if not an oversupply in the US (Camilli & Hira, 2019). Our study relies on the input of business executives who employ STEM workers for a more qualitative view of their experiences in the current labor market and their thoughts on the future of the STEM workforce.

Potential shortages in STEM graduates and STEM workers require a coordinated intervention from parents, educators, businesses and the government, as the "learning ecosystem" (Krishnamurthi et al., 2014), along the educational and career pipeline. We designed this study to focus on the perspectives of CEOs, as the leaders, and thus reliable informants on the STEM market. We limited our study to businesses in Georgia and explored the mechanisms by which these various groups may impact and/or sustain the supply of skilled STEM workers. We sought to understand:

RQ1: How do parents impact the supply of STEM workers?

RQ2: How do educators impact the supply of STEM workers?

RQ3: What should businesses do to sustain the supply of STEM workers?

RQ4: What should the government do to sustain the supply of STEM workers?

The paper continues as follows. First, we present the importance of parents, educators, businesses, and government regarding pursuing STEM educational and career paths. Then, in the method section, we present our data collection, analysis, and findings. Finally, we discuss the implications of this study, discuss ideas for future research, and present our conclusions.

LITERATURE REVIEW

To address our research questions, we began with a review of the history of STEM education and STEM shortages in the US and other countries. Then, we explored the stakeholders in the ecosystem who impact the development of a sustained STEM workforce: parents, educators, industry, and government. This ecosystem is the foundation for understanding the possible inputs and the various outcomes relevant to a sustained STEM workforce.

STEM HISTORICAL OVERVIEW

In the US, the STEM education system we know today has been shaped by several milestones, including early design-based instruction, project-based learning in technology education and engineering, and technology education as a subject integrator (Kelley, 2012). During the first milestone, the design-based instructions pioneers advocated for a hands-on approach to teaching, which proved to be such a success with kids that Froebel educational toys were marketed to introduce engineering and design concepts for kids at an early stage (Kelley, 2012). The second milestone marked the integration of technology education with engineering by teaching mathematics, science, and engineering concepts through practical applications (Kelley, 2012). This movement led to the foundation of the first engineering department in the US at what is now called the Rensselaer Polytechnic Institute (Kelley 2012). According to Kelley (2012), "Many people during the decade from 1880-1890 had great opposition to manual training in K-12 classrooms, and as a result, the gap between academic subjects and hands-on activities began to widen" (p. 36). The last milestone emphasized using technology in teaching science, engineering, and mathematics subjects through practical hands-on activities in the classroom. Recognizing students' need to improve their skills in these subjects, pioneers in that era suggested weaving technology into teaching these subjects by placing its concepts in context (Kelley, 2012).

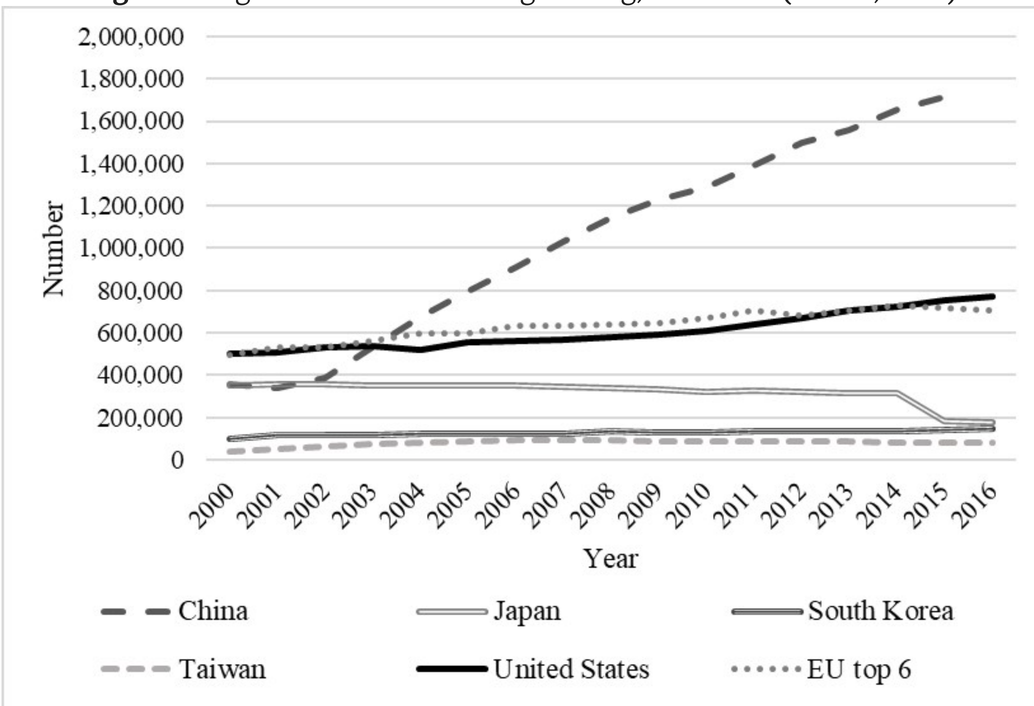
The STEM acronym is a rather contemporary concept. The National Science Foundation (NSF) initially formalized science, mathematics, engineering, and technology, or SMET, in the 1990s (Sanders, 2008). A director at NSF, Judith Ramaley, is credited with changing the acronym to STEM around 2001 (Chute, 2009). The country soon became concerned that other countries could be outpacing the US as expressed convincingly in the findings of the government-appointed Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology, which included Nobel laureates, CEOs, major university presidents, and former presidential appointees:

> "Having reviewed trends in the United States and abroad, the committee is deeply concerned that the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength" (National Academy, 2007, p. 3).

The committee feared the potential repercussions of US scientific and technological decline if appropriate measures were not taken and found that high priority should be given to solving problems within the STEM educational pipeline (National Academy, 2007, p. 5). In 2006, then US President George W. Bush highlighted the importance of expanding government expenditures and involvement to ensure that the US would remain competitive in STEM-related fields. One of his assertions was to "… encourage children to take more math and science, and to make sure those courses are rigorous enough to compete with other nations" (Bush, 2006, para. 52). The sense of urgency created by the government had an effect as Daugherty noted in 2013, "STEM education has since become perhaps the largest reform movement in PK-12 education over the last decade" (p. 1).

The historical trends at the international level confirm that stakeholders in the US STEM pipeline still have reason to be concerned about STEM education. As shown in Figure 1, the US has seen slow growth in the number of STEM-related bachelor's degrees awarded, especially compared to China. While the US has seen growth in STEM-related degrees, from 503,467 degrees in 2000 to 768,291 degrees in 2016, China has experienced much more significant growth, from 359,478 degrees in 2000 to over 1.7 million degrees in the same time period (NCSES, 2019). In 2014, the US accounted for approximately 10 percent of science and engineering degrees, falling behind both India and China, whose students earned 25 percent and 22 percent of those degrees, respectively (Granovskiy, 2018).

Figure 1: Degrees in science and engineering, 2000-2016 (NCSES, 2020)



STEM WORKFORCE SHORTAGE: A DEBATE

There is an ongoing debate about whether the US is experiencing a shortage or surplus in the STEM workforce. While shortages have been reported in careers such as petroleum engineering and software development, there were surpluses in other fields, such as biotechnology, chemistry, and pharmaceuticals (Xue & Larson, 2015). Thus, both the shortage and surplus arguments can be supported, depending on factors such as education level, competencies, industry, and specific STEM careers (Carnevale et al., 2011; Xue & Larson, 2015). For example, traditional measures of the STEM workforce shortage or surplus utilized research and development (R&D) expenditures, which fail to capture the full picture of the STEM workforce (Carnevale et al., 2011). Relying on the raw number of STEM workers is also problematic. In 2011, the Standard Occupation Classification Policy Committee created guidelines to classify STEM workers, which were formally accepted the following year (USBLS, 2012). Using this updated guideline, it was found that there were approximately 7.2 million STEM workers, which accounted for 6 percent of the United States workforce (Landivar, 2013). However, with the projected job growth in the STEM field, it is only natural to assume that the number of STEM workers will also grow.

Further complicating the debate is that a large percentage of STEM graduates are not employed in a STEM career field (Landivar, 2013). In 2011, only 26 percent of science and engineering graduates were employed in STEM occupations, whereas 73 percent were employed in fields such as non-STEM management, accounting, or law, among others (Landivar, 2013). These mismatches between degree and career indicate that the leaks in the STEM pipeline extend beyond education. Despite the projected growth in STEM fields, and an increase in individuals obtaining STEM degrees, a significant percentage of future STEM jobs are likely to be filled by individuals whose educational backgrounds are from other disciplines.

Scholars have sought to understand the perspectives of various stakeholders, including managers and recruiters, who are concerned with STEM workforce shortages or surpluses (Xue & Larson, 2015). We encourage the study of the STEM pipeline and potential leaks using key stakeholders' perspectives of the STEM workforce. To better understand this ecosystem, next, we consider how parents, education, industry, and the government influence the STEM pipeline.

THE VITAL ROLE OF PARENTS

Previous studies have discussed the vital role of parents, as the first line of contact, on children's educational and career pathways. The concept of what encompasses parental support is broad, and the act of support can take many shapes and forms. The top three forms of parental support addressed in the literature are: providing financial assistance, engaging in the student's educational and extracurricular activities, and setting expectations regarding academic performance (e.g., Seginer, 1983; Houtenville & Conway, 2008; Fang et al., 2018).

Parents are not only responsible for the well-being of their children but also for the development of their belief in their abilities to achieve goals (Coleman, 2018; Mariani, 2019). If an individual believes that achieving a degree/career in a STEM field is obtainable, their likelihood to pursue such a degree increases.

Considering STEM as an educational and career choice, parental support was demonstrated to factor in children's decision to enter or even remain in STEM (Rozek et al., 2017; Mangu et al., 2015). Furthermore, as the most proximal influencer, parents have a strong potential to impact children's decisions about STEM as an educational and/or career option (White & Shakibnia, 2018). Research has shown that parental engagement shapes children's values and motivation related to STEM fields (Harackiewicz et al., 2012). Parental engagement is multidimensional and includes participation in a student's school and extracurricular events, assisting with schoolwork, and assisting in engaging with community resources (Lee & Shute, 2010). Parental engagement is likely to impact a child's perceived utility of STEM courses, affecting his or her career path (Nugent et al., 2015). Parental expectation, defined as parental interests in their child's academic achievements in school, has been shown to impact an individual's pursuit of STEM career and their academic achievement (Halim et al., 2018; Yamamoto & Holloway, 2010).

THE ESSENTIAL ROLE OF EDUCATION

Whether in K-12 or higher education, educators (both teachers and faculty) and schools (primary, secondary, colleges, and universities) are essential to the integration of students and workers into the STEM pipeline. Educators are one of the most important assets regarding the STEM pipeline. They have the potential to instill not only knowledge but also interest in STEM subjects from an early age (i.e., K - 12) and thus may lead students to the pursuit of STEM degrees.

During the K-12 education years, students gain knowledge on an array of subjects, including those critical to STEM. US education systems have developed various programs to address a shortage of STEM teachers. For instance, the Guilford County school system hired individuals with STEM backgrounds to teach while receiving teaching certification (Will, 2018). A related issue is the significant percentage of teachers in the K-12 education system that hold degrees in subjects other than those in which they teach (Granovskiy, 2018). This lack of STEM degree attainment could potentially impact the teacher's perceived efficacy to teach STEM subjects.

In higher education, universities are taking initiatives to expose high school students to STEM fields and career possibilities. For example, the University of Alabama System (UAS) sponsors the STEM Academy, a community-based partnership, which invites high school students to campus for a week in the summer for classroom instruction and hands-on experiences to learn about cutting-edge career options in STEM fields (UAS, n.d.).

INDUSTRY ENGAGEMENT

Engaging in events and activities with schools and the local communities is one of many ways industries are addressing leakages in the STEM talent pipeline. Technology firms and business giants are pledging large sums of money to fund K-12 education programs, appropriating an excess of $300 million to further STEM education (Stych, 2017). For example, organizations are partnering to provide professional development scholarships for middle and high school teachers who want to learn to teach a STEM subject (Microsoft, n.d.).

Because they understand the significance of STEM in higher education, many industries often provide students and student-employees with scholarships and grants (*21CF and PepsiCo*, 2017). Acknowledging that almost half of STEM graduates do pursue a STEM career (Graf et al., 2018), industries are adopting some recruiting techniques such as hiring bonuses, loan forgiveness or repayment incentives, and pay/benefit incentives. They are also exposing students to potential STEM careers and offering alternative pathways to access STEM education and practical experience in the form of community-school partnerships and internships. For instance, Cisco participates in Girls in ICT Day (ITU, n.d.) in which female students get exposure to the latest technologies and engage with industry professionals, in the hope of encouraging them to pursue careers in STEM fields.

Afterschool programs have recently begun to include STEM curriculum. This innovation allows youth to engage in STEM-focused activities, developing many of the skills necessary for future STEM pursuits (Krishnamurthi et al., 2014; Mangu et al., 2015; Watters & Diezmann, 2013; Weber, 2011). Many programs are adopting hands-on projects (e.g., code camps, the robot builds), allowing students to apply concepts that are learned in school (Krishnamurthi et al., 2014). Industry stakeholders are acknowledging the importance of allowing students of younger ages access to STEM concepts through activities.

GOVERNMENT INVOLVEMENT

Government involvement in feeding the STEM pipeline has been a major concern to policymakers since the introduction of STEM by the NSF. At the federal level, generally acting through key agencies such as the NSF and Department of Education, the US government has established annual appropriations to fund STEM education in formal and informal settings (Granovskiy, 2018; Butz et al., 2004). For example, the NSF has awarded $50 million in grants to provide STEM opportunities for K-12 students (NSF, 2018).

At the state level, partnerships between state governments and industries are taking place to develop STEM skills through funding specialized labs in local schools (Curran, 2019). Such initiatives are driven by the belief that these state-of-the-art labs impact student engagements. However, despite the increases in funding and the initiatives to partner with other groups, performance measures (i.e., graduation rates and national test scores such as the ACT and the NAEP) indicate little to no growth in

STEM knowledge, showing continued poor performance relative to other countries (Lips & McNeill, 2009).

Scarce research on the collaboration of parents, educators, industry, and government exists. This study seeks insights from C-suite business executives who employ STEM workers regarding the role of each of the ecosystem members who may impact the ability of the US to sustain a skilled STEM workforce. Specifically, we asked CEOs what each of these groups must do if the US is to sustain a skilled STEM pipeline.

RESEARCH METHOD

The purpose of this research was to explore the roles of parents, educators and schools, businesses and community partners, and government in establishing and maintaining a skilled STEM workforce. We sought the perspectives of CEOs from different organizations since CEOs are required to know their organizations' strengths, needs, and challenges. We collected data from 45 CEOs in Georgia. The capital city, Atlanta, ranked 3rd in 2019 in cities with the most Fortune 500 headquarters and is home to the headquarters for familiar brands including The Coca-Cola Company, Delta Air Lines, The Home Depot, and United Parcel Service (UPS) (SelectGeorgia, n.d.). With the number one ranked workforce training program in the country, Georgia Quick Start (Georgia, n.d.), the state is an appropriate level of analysis to study CEO perspectives on the STEM pipeline.

This paper is part of an economic development project that sought C-suite executives' and managers' opinions from multiple US states. We used the services of Qualtrics to collect data from participants on our behalf over a three-month period. State-level demographic data were not included as part of the study. We contracted with Qualtrics to perform the work and to develop, deliver, and assure the quality of the research project. Thus, participants received a monetary incentive for completing the survey from Qualtrics, and we received the requested sample size, eliminating the need to contact the participants ourselves.

Table 1 shows the breakdown of respondents by their industry classification. The majority of organizations have annual STEM-related research and development budget of $500,000 to one million dollars and an estimated average annual sales of more than 10 million dollars. More details about the surveyed industries are shown in Table 1. Survey items are provided in Appendix A.

We cleaned the data, and one response was removed due to incomplete answers, which resulted in 45 usable responses. For the textual analysis of the questions, we used minemytext, a cloud-based application. The minemytext system allowed us to capture the probabilistic thematic coverage and to explore factors that may lead to more STEM-capable graduates and, ultimately, a sustained STEM workforce in the US. We used the minemytext tool because it is a data-driven, fully automated, and unsupervised textual analytical tool that eliminates researchers' biases. This tool assumes that all written texts have a pre-defined set of themes. Building on that, the tool searches for similar themes, which are conveyed by the words, and cluster them into sets. Minemytext then interprets these sets as topics because the words tend to have similar meanings. As a result, unstructured texts were able to be clustered into thematic categories. The algorithm that the application uses to discover these topics is the Latent Dirichlet Allocation (LDA) algorithm. Therefore, by using minemytext, the results of the analysis will be interpreted as probabilistic topics discovered and are purely data-driven from the analyzed text.

Table 1: Descriptive Statistics

Industry Classification	Count	Average Annual Sales	Count
Advanced Manufacturing	9	*Under $500K*	1
Automotive	1	*$501K – 1 Million*	4
Chamber/Economic Development	1	*$1.1 – 2.5 Million*	6
Chemical Products and Plastics	1	*$2.6 – 5 Million*	4
Education	1	*$5.1 – 10 Million*	5
Energy Technologies	3	*$10.1 – 20 Million*	3
Healthcare	3	*$20.1 – 50 Million*	4
Professional and Business Services	24	*$50.1 – 100 Million*	11
State and Local Government	1	*$100.1 – 500 Million*	3
Transportation, Logistics, and Distribution Services	1	*Over $500 Million*	4
Number of Employees	**Count**	**Percentage of Employees in STEM Jobs**	**Count**
<100	13	*<20%*	4
100-249	12	*21-40%*	15
250-499	9	*41-60%*	10
500+	11	*61-80%*	10
		81-100%	6
Export Overseas	**Count**		
No	24		
Yes	21		

As researchers, we need to only specify the number of topics to be extracted a priori since topic modeling is an unsupervised technique. Based on the criteria put forth by Bouma (2009) and Lau et al. (2014), multiple iterations had to be applied to determine the most suitable number of topics to extract. For instance, the two-topic model for the government group yielded topic themes that were most pronounced and most distinguishable when compared to models with four to six-topic models. For further information on topic modeling, please refer to the tutorial offered by Debortoli et al. (2016).

RESULTS AND DISCUSSION

The general aim of this study was to uncover CEOs' perspectives about the current status of the STEM pipeline in the US. More specifically, we examined 1) the role of parents in STEM educational and career choices for children, 2) the role of educators and schools in promoting STEM disciplines, 3) the potential ways to engage industry in the promotion of STEM disciplines, and 4) the role of the government in supporting STEM disciplines.

Table 2 summarizes the results of our analysis, including the topics identified for parents, educators, business, and government, along with quotes/exemplary content and frequently used words. For example, the government group has two topics. Topic one is characterized by the words "awareness," "mandatory," "curriculum," "available," and "program." These words and reading through the exemplary content generated by these clustered quotes that minemytext deemed relevant allowed us to infer that the first topic discussed by the CEOs is about attracting STEM graduates to be part of the STEM workforce. In the following sections, each discovered topic for each group is discussed.

ROLE OF PARENTS

The first topic that emerged focused on the role of parents we labeled "**Support children to develop STEM knowledge.**" CEOs expressed their concern about parents' lack of support in developing STEM knowledge for their children. Our respondents indicated that it is on the parents to support, if they can, or seek ways to support their children's STEM knowledge, if they can, by partnering with other entities such as schools and educators. As one respondent stated:

> [Parents should] encourage their children more to learn and study in this field. The only effective system for bringing kids into the field is one that requires some degree of buy-in from the parents into this. Passion unadmired often turns into resentment and that can poison perceptions for years […] They should be incorporating it in their daily lives. For instance, [parents need to put effort into] recognizing and supporting natural abilities of their children and then helping them to enroll in additional opportunities to foster development of their talents.

Table 2: *Topic Modeling Results*

Topic ID	Five Most Frequently Used Words	Quotes/Exemplary Content	Interpretation of the Topic
Parent			
1	*Knowledge, support, help, guide, development*	*Recognizing and supporting natural abilities of their children and then helping them to enroll in additional opportunities to foster development of their talents*	*Support children to develop STEM knowledge*
2	*Career, choice, option, industry, opportunity*	*[Parents] play the role in letting their children know that STEM is an available career choice.*	*Highlight STEM as a career choice*
Educators			
1	*Education, choice, option, available, potential*	*They should let kids know it is an option. Let them know what this option is about.*	*Encourage STEM as an educational option*
2	*Career, opportunity, viable, pursue, field*	*They should show children how essential it is for them to learn and pursue careers in this field.*	*Encourage STEM as a career option*
Industry and Business			
1	*Curriculum, help, advise, involve, courses*	*Schools and educators need to ask businesses to help with the STEM curriculum. They know what they need to fill the jobs.*	*Get involved in advancing STEM and STEM curriculum*
2	*Awareness, education, program, available, advertise*	*Businesses can help by having local events for STEM to be a part of political campaigns and by implementing more advertisements.*	*Raise awareness about STEM education*
Government			
1	*Awareness, mandatory, curriculum, available, program*	*The government needs to make STEM a mandatory school program requirement.*	*Foster interest in STEM education*
2	*Workforce, support, attract, encourage, local*	*The government needs to stop recruiting from outside the US and raise up US talent.*	*Attract STEM graduates to the STEM workforce*

We labeled the second topic that emerged "**Highlight STEM as a career choice.**" The CEOs indicated that parents are not only encouraged to support the development of STEM knowledge for their children but also are needed to highlight STEM as a career choice. Parents should encourage children to consider STEM college classes and jobs, as well. As one of the respondents mentioned:

> [Parents should] always be involved in their [children's] STEM occupations [...] They should only play the role in letting their children know that STEM is an available career choice and that could be the best option […] Parents should be mindful that not everyone is cut out for every job that involves this. So, one can't say a parent or anyone

else should suggest or push someone to do something that they may not be good at or interested in.

ROLE OF EDUCATORS

The first topic in this category that emerged, we labeled "**Encourage STEM as an educational option.**" CEOs indicated that to develop a steady, sustainable STEM pipeline, we need to start with the educational system. They stated that educators are the best point of contact to inspire children in K-12, and college and universities; educators should be the ones introducing STEM to children or at least supplementing what the parents have done. In short, educators need to seek out children for the program. As one of the respondents mentioned:

> At the Department of Education, we share the President's commitment to supporting and improving STEM education. Ensuring that all students have access to high-quality learning opportunities in STEM subjects is a priority […] [Educators should be] seeking and nurturing children's gifts and abilities, reaching out to connect the children with higher education opportunities in their communities in league with parents. [Educators] should make sure all children are paying attention to the curriculum, and make things clear so everyone understands.

Another respondent echoed the idea that educators play a pivotal role in STEM promotion, stating:

> [Schools] should play a major role. [Educators should be] teaching but in a different way than parents [...] Educators should be leaders and knowledgeable in this field. [Educators should] guide children to a good STEM educational path that will help the children reach success […] [Schools] should have more courses to offer for children to help them be more aware about STEM discipline and opportunities […] [Educators] should be helping children choose a STEM subject and educate them on that subject.

We labeled the second topic that emerged, "**Encourage STEM as a career option.**" Schools and educators' roles are not just about providing the proper education and the availability of courses that cover STEM subjects. Schools and educators, side-by-side, must encourage students to embrace a career in STEM as well. They should show children how essential it is for them to learn and pursue careers in this field. As one of the respondents stated:

> Educators should encourage STEM related careers. More importantly, educators need to take an active role in educating students on the top careers in STEM, emphasizing the importance of each and how they relate to our country's strength and prominence. They are the advisors of their STEM career choices, and the educators about these jobs […] They should educate the students as well as the public about the direct benefits of STEM industry and working in that industry.

ROLE OF INDUSTRY

The first topic that emerged focused on the role of the industry we labeled "**Raise awareness about STEM education.**" In the United States, access to STEM programs is most commonly provided by schools and communities. CEOs suggested businesses need to host local events in collaboration with local communities and schools, to make it part of their strategic campaign to advertise and be advocates for the STEM field. This idea is especially evident in the comment of one respondent who stated:

> Business should play a role in educat[ing] [students] why [STEM] is a good program, and why it would be helpful for them […] Get the word out there. [Businesses should]

> spread awareness by having special events and demonstrations to show business owners how essential this is to the growth of their businesses… through job fairs, workshops […] Offer programs for students that go beyond internships. Also, partner[ing] with other businesses can make jobs in the industry known to STEM graduates.

The second topic that emerged focused on the role of the industry we labeled "**Get involved in advancing STEM and STEM curriculum."** Businesses can suggest to educators at the K-12 and college/university levels what they need to fill the STEM jobs, and educators can respond accordingly. To sustain the STEM pipeline from school to workplace, schools need to reflect on the skillset needed and always try to keep up to date with what is needed to get a STEM job. This involvement can help tailor degree paths to STEM careers based on the feedback from STEM employers. One respondent put it this way:

> Schools and educators need to ask businesses to help with the STEM curriculum. [Businesses] want a STEM graduate that is work ready. What is better than hearing it directly from us? If educators can incorporate in their courses what we need from a STEM graduate that would crucial […] [Businesses] have relations with schools and local communities and achieving that should not be problem. It is doable […] We all need to collaborate to make this work.

Another respondent commented about advancing the STEM field and succinctly stated:

> Plenty of business money exists in the US especially for large tech corporations - start local community programs to capture the talents of our youth at early ages and follow through with their education.

ROLE OF THE US GOVERNMENT

The first theme that emerged in regards to the role of the US government we labeled **"Attract STEM graduates to the STEM workforce."** CEOs indicated that parents, educators, and businesses' efforts are not enough if not supported and complemented by those of the US government. Respondents urged the US government to take an active role in finding a job placement for STEM graduates in the STEM industry. As one respondent stated:

> The government can play a critical part. [The government] should stop recruiting outside the US and raise up US talent. Our children have the potential to fill these STEM jobs if provided with the proper incentive, quality education, and opportunity of a good career in STEM […] [The government] needs to start working with us and not against.

We labeled the second theme that emerged **"Foster interest in STEM education."** CEOs indicated that government support is needed to foster an interest in STEM education. For K-12, CEOs proposed that the government should make STEM subjects mandatory. Another suggestion some respondents had was that the government should assist schools and educators in encouraging STEM courses in educational institutions. As one of our respondents mentioned:

> [The government] should provide STEM as mandatory school program requirements and even adding this to the college curriculum […] Doing so will bring more awareness of needs and opportunities as well as interest in STEM education.

IMPLICATION AND FUTURE RESEARCH

Our research has several important implications for scholars, business executives and managers, educators, government leaders, and other stakeholders who are interested in sustaining the STEM pipeline. The findings reveal that CEOs recognize the interconnectedness between parents, educators, businesses and industry, and government as key players in supporting a sustainable skilled STEM workforce within the US. The interdependence of these members of the ecosystem is critical for achieving a sustained STEM pipeline.

CEOs recognize that parents should be directly involved in helping a child become interested in STEM and prepared for STEM careers. Parents should expose their children to STEM-related activities and classes during their primary and secondary education and later to STEM-related career opportunities. Supplementing their educations based on their talents and passions was suggested. One effective way for parents to foster interest in STEM careers is to expose their children to STEM jobs. This connection can be made in a myriad of ways, such as career fairs and job shadowing days. Some education systems, especially when one considers the urban/rural divide, may not offer the same quality or quantity of exposure opportunities. Parents should consider innovative approaches like the Smart Futures website, a not-for-profit career development website for children and young adults. After completing some surveys and activities, Smart Futures provides career and career cluster information for parents and children to explore (SmartFutures, n.d.). Further, using the same website, parents and children can even go as far as to create a career plan for implementation.

CEOs indicated that educators should be introducing children to STEM, supplementing what might be happening at home with parents. Educators are expected to inspire and encourage students who have interests and talents related to STEM. To encourage STEM as an educational option, universities themselves play a pivotal role in the development and advancement of STEM efficacy and pedagogy at large. One such university that is seemingly at the forefront of this engagement initiative, and which should be an example to others, is Georgia Tech and its Center for Education Integrating Science, Mathematics, and Computing (CEISMC, n.d.). CEISMC connects Georgia Tech's faculty members and student body to pre-K -12 communities. In 2018, CEISMC engaged with over 39,000 students, in both STEM outreach and extracurricular activities, in over 75 Georgia school districts (CEISMC, n.d.). This outreach has expanded beyond the students by engaging over 1,720 STEM teachers, further increasing the likelihood of sealing STEM pipeline leaks. This engagement is best exemplified through their various outreach programs. Programs Enriching Accelerated Knowledge in STEM (PEAKS) is one such program, where students have access to over 24 hands-on programs throughout the summer. PEAKS prides itself in the provision of activities that would otherwise be unavailable to these students in their traditional classroom settings (Pitrone & Taylor, 2018).

CEOs had integrative insights on the role of business and industry. To support and sustain a STEM workforce, CEOs stated that business and industry need to (1) raise awareness about STEM education and (2) advance STEM by getting involved in STEM curriculum. Being an advocate of STEM disciplines in the local communities and schools was suggested to raise awareness. Industry partnerships are a great way to accomplish this goal. For example, Georgia hosts Georgia STEM Day, which has engaged with more than one million students since its adoption (TAG-Ed, n.d.). Business professionals in STEM may speak to students about their careers or host student field trips to their businesses, for example.

In terms of influencing curriculum, business and industry should pursue participation in advisory boards for high schools and universities. These boards often provide the perspective of the industry regarding desired skillsets and learning outcomes when a program is being launched or updated. A broader example of industry partnering with educators is the TAG Education Collaborative (TAG Ed) that was formed by the Technology Association of Georgia (TAG-Ed, n.d.). TAG Ed is a central hub for industry and community partnership within the state of Georgia, engaging with 102 community partners which impact the STEM pipeline, specifically targeting K-12 education. TAG Ed has various programs which are sponsored and serviced by industry partners. Further, business leaders have formed partnerships with institutions of higher education to advance and strengthen STEM education at the university level. The Terry College of Business at the University of Georgia provides two such examples: The Silicon Valley Advisory Council and the STEM MBA program (Terry, n.d.).

CEOs suggested that the government's contribution in the ecosystem was essential to attracting graduates to the STEM workforce. CEOs went as far as to say that some STEM curriculum should be mandatory. Additionally, CEOs suggested that the government should strive to limit reliance on or restrict the use of STEM workers from outside the US. As with the other components in the ecosystem, the government is challenged with raising awareness about STEM disciplines and attracting graduates to the STEM workforce. Georgia is the first state to implement both STEM and STEAM (Science, Technology, Engineering, Arts and Mathematics) certifications for their public schooling system, in an attempt to prepare students for various career fields in the future (STEM, 2018b). As of 2018, 68 schools are STEM/STEAM certified (STEM, 2018b), increasing STEM awareness at various levels: the student level, the parental level, the educator level, and the stakeholder level. Over 70 city and county school systems are currently seeking to become STEM/STEAM certified (STEM, 2018b). Results have been promising since STEM/STEAM certification implementation with 8th grader mathematic proficiency averages increasing by approximately 11 percentile points over a three-year period (STEM, 2018a).

We hope that this research inspires other interested researchers to uncover other stakeholders' perspectives with regard to what can be done to sustain a healthy STEM pipeline. Scholars may use these findings to guide their research in areas related to the STEM pipeline. For example, future research may consider the opinions of parents regarding their children's choices about pursuing STEM subjects and what motivates children to pursue STEM majors and, eventually, STEM careers. In addition, future research could gain deeper insights from school administrators about any trends they might notice among students when they consider STEM subjects or STEM majors. Also, future research can seek input from educators about their pedagogies and preparedness for teaching STEM subjects, what resources they need to deliver effective instructions, and what skills they lack in terms of STEM teaching effectiveness. Theoretical frameworks could be developed by studying the ecosystem in different regions and countries to identify patterns that could influence additional research. The case study methodology should be considered when successful policies and programs are discovered to share generalizable findings. Another idea would include identifying mechanisms for assessing and evaluating collaborations and initiatives among members of the learning ecosystem. Future research could take a number of routes to gain insights from any of the stakeholders in the hope of integrating these perspectives to create a sustainable STEM pipeline governed by an ecosystem of stakeholders who are willing to keep the communication open and clear.

CONCLUSIONS AND LIMITATIONS

We sought to glean insights from CEOs, as C-suite executives and industry leaders, about the role of parent, educators, businesses, and government in preparing a sustained skilled STEM workforce pipeline. CEOs' perspectives on the STEM workforce ecosystem were analyzed to identify key topics. The CEOs reminded us that coordinated collaboration between each ecosystem component provides us the greatest chance for success at patching the "leaks" in the STEM workforce. We must continue to focus on educating and equipping parents and early childhood educators to incorporate STEM activities into daily life and inspire children. We should advise secondary, college, and university educators and administrators to incorporate business and industry leaders' feedback into the curriculum, courses, and programs through participation in advisory boards and partnerships on career pathways. We implore communities and governments to support these endeavors in the short- and long-term because the need for skilled STEM workers will continue to grow in the future.

As with any research, our study has limitations. The 45 CEOs spanned multiple industries with different sizes, but all respondents were from one state. A larger sample, perhaps including Fortune 500, private companies, and public-sector executives, could provide more diverse implications for creating a sustainable STEM pipeline.

APPENDIX A: Survey Items

Item Number	Question
1	*What is your current role at your company?*
2	*What is your industry classification?*
3	*Estimate the current number of employees you have.*
4	*What percent of your employees occupy STEM or STEM-related jobs?*
5	*Should there be a role for the government to play in promoting STEM workforce dynamics? If yes, what role should it play?*
6	*What are the major challenges associated with the STEM infrastructure and the government's role in promoting STEM workforce dynamics?*
7	*What role should parents play in making STEM educational choices for children?*
8	*What role should educators play?*
9	*Is information about STEM jobs available for both parents and students?*
10	*What are the potential ways to engage business, industry, and other community partners to advance STEM?*
11	*Are high schools and colleges in your state equipping students with the proper skills for STEM-related jobs?*
12	*Are enough quality/competitive individuals being produced for STEM occupations in your state?*

REFERENCES

21CF and PepsiCo award $200,000 scholarships to women in STEM as part of 'The search for hidden figures' contest. (2017, January 13). 3BLMedia. https://www.3blmedia.com/News/21CF-and-Pepsico-Award-200000-Scholarships-Women-Stem-Part-Search-Hidden-Figures-Contest

Bouma, G. (2009). Normalized (pointwise) mutual information in collocation extraction. *In Proceedings of the Biennial GSCL Conference, Potsdam*, Germany, pp. 31–40.

Bush, G. W. (2006). State of the Union Address by the President. The White House President, George W. Bush. https://georgewbush-whitehouse.archives.gov/stateoftheunion/2006/

Butz, W. P., Kelly, T. K., Adamson, D. M., Bloom, G. A., Fossum, D., & Gross, M. E. (2004). Will the scientific and technology workforce meet the requirements of the federal government? Summary. Rand Corporation. https://www.rand.org/pubs/monographs/MG118.html

Camilli, G., & Hira, R. (2019). Introduction to special issue-STEM workforce: STEM education and the post-scientific society, *Journal of Science Education and Technology, 28*, 1-8.

Carnevale, A. P., Smith, N., & Melton, M. (2011, October 20) *STEM*. Georgetown University. https://files.eric.ed.gov/fulltext/ED525297.pdf

Center for Education Integrating Science, Mathematics and Computing (CEISMC) Georgia Institute of Technology - College of Sciences. (n.d.). *About CEISMC.* https://www.ceismc.gatech.edu/about

Charette, R. N. (2013). The STEM crisis is a myth. *IEEE Spectrum, 50*(9), 44-59. https://spectrum.ieee.org/at-work/education/the-stem-crisis-is-a-myth

Chute, E. (2009). STEM education is branching out: Focus shifts from making science, math accessible to more than just brightest. Pittsburg Post-Gazette. https://www.post-gazette.com/news/education/2009/02/10/STEM-education-is-branching-out/stories/200902100165

Coleman, J. S. (2018). *Parents, their children, and schools.* Routledge.

Curran, E. (2019, October 07). *Volkswagen eLabs facilitate design thinking and digital fabrication experiences for Hamilton county students.* TSIN. https://www.tsin.org/volkswagen-e-labs-facilitate-design-thinking-and-digital-fabrication-experiences-for-hamilton-county-students

Daugherty, M. K. (2013). The prospect of an "A" in STEM education. *Journal of STEM Education: Innovations and Research, 14*(2), 10-15.

Debortoli, S., Müller, O., Junglas, I. A., and Vom Brocke, J. (2016). Text mining for information systems researchers: An annotated tutorial. *Communications of the AIS,* pp. 1–30.

Dillon, T. W., Reif, H. L., & Thomas, D. S. (2016). An ROI comparison of initiatives designed to attract diverse students to technology careers. *Journal of Information Systems Education, 27*(2), 105-117.

Exter, M., & Lehman, J. (2016). An academic program profile: Purdue University. *Performance Improvement, 55*(5), 14-33.

Fang, S., Huang, J., Curley, J., & Birkenmaier, J. (2018). Family assets, parental expectations, and children educational performance: An empirical examination from China. *Children and Youth Services Review, 87*, 60–68.

Georgia Department of Economic Development. (n.d.). *Workforce & Education.* https://www.georgia.org/competitive-advantages/workforce-education

Graf, N., Fry, R., & Funk, C. (2018). 7 Facts about the STEM Workforce. https://www.pewresearch.org/fact-tank/2018/01/09/7-facts-about-the-stem-workforce/

Granovskiy, B. (2018, June 12). Science, technology, engineering and mathematics (STEM) education: An overview. Congressional Research Service (CRS Report R45223). https://crsreports.congress.gov/product/details?prodcode=R45223

Halim, L., Rahman, N., Zamri, R., & Mohtar, L. (2018). The roles of parents in cultivating children's interests towards science learning and careers. *Journal of Social Sciences, 39,* 190-196.

Harackiewicz, J. M., Rozek, S. C., Hulleman, C. S., & Hyde, J. S. (2012). Helping parents to motivate adolescents in mathematics and science: An experimental test of a utility-value intervention. *Psychological Science, 23*(8), 899-906.

Houtenville, A., & Conway, K. (2008). Parental effort, school Resources, and student achievement. *Journal of Human Resources*, *43*(2), 437-453.

International Telecommunication Union (ITU). (n.d.). *Girls in ICT Day.* https://www.itu.int/en/ITU-D/Digital-Inclusion/Women-and-Girls/Girls-in-ICT-Portal/Pages/Portal.aspx

Kelley, T. R. (2012). Voices from the past: Messages for a STEM future. *Journal of Technology Studies, 38*(1), 34-42.

Krishnamurthi, A., Ballard, M., & Noam, G. G. (2014). Examining the impact of afterschool STEM programs. *Afterschool Alliance.* https://files.eric.ed.gov/fulltext/ED546628.pdf

Landivar, L. C. (2013). The relationship between science and engineering education and employment in STEM occupations. *American Community Survey Reports.* https://www2.census.gov/library/publications/2013/acs/acs-23.pdf

Lau, J., Newman, D., & Baldwin, T. (2014). Machine reading tea leaves: Automatically evaluating topic coherence and topic model quality. *In Proceedings of the European Chapter of the Association for Computer Linguistics.*

Lee, J., & Shute, V. J. (2010). Personal and social-contextual factors in K-12 academic performance: An integrative perspective on student learning. *Educational Psychologist, 45*(3), 185-202.

Lips, D., & McNeill, J. B. (2009, April 15). *A new approach to improving science, technology, engineering, and math education.* The Heritage Foundation. https://www.heritage.org/education/report/new-approach-improving-science-technology-engineering-and-math-education

Mangu, D. M., Lee, A. R., Middleton, J. A. & Nelson, J. K. (2015). Motivational factors predicting STEM and engineering career intentions for high school students. *2015 IEEE Frontiers in Education Conference Proceedings,* 2285-2291.

Mariani, M., Sink, C. A., Villares, E., & Berger, C. (2019). Measuring classroom climate: A validation study of the My Child's Classroom Inventory–Short Form for Parents. *Professional School Counseling*, *22*(1), 1-14. 2156759X19860132.

Microsoft. (n.d.). *Inspire girls in STEM; Making a difference for girls in STEM.* https://www.microsoft.com/en-us/corporate-responsibility/skills-employability/girls-stem-computer-science

Moreno, N., Tharp, B., Vogt, G., Newell, A., & Burnett, C. (2016). Preparing Students for Middle School through After-School STEM Activities. *Journal of Science Education and Technology, 25*(6), 889-897.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. (2007). Rising above the gathering storm: Energizing and employing America for a brighter economic future. The National Academies Press.

National Center for Science and Engineering Statistics (NCSES). (2019, September). *Higher education in science and engineering.* NSF NSB Science & Engineering Indicators. https://ncses.nsf.gov/pubs/nsb20197/international-s-e-higher-education#figureCtr724

National Center for Science and Engineering Statistics (NCSES). (2020, January). *The State of US science and engineering 2020*. NSF NSB Science & Engineering Indicators. https://ncses.nsf.gov/pubs/nsb20201/data

National Science Foundation (NSF). (2018, November 15). *NSF awards $50M in grants to improve STEM education.* https://www.nsf.gov/news/news_summ.jsp?cntn_id=297236&org=NSF&from=news

Noonan, R. (2017). *STEM Jobs: 2017 Update*. Office of the Chief Economist. US Department of Commerce (ESA Issue Brief #02-17).

Nugent, G., Barker, B., Welch, G., Grandgenett, N., Wu, C., & Nelson, C. (2015). A model of factors contributing to STEM learning and career orientation. *International Journal of Science Education, 37*(7), 1067-1088.

SmartFutures (n.d.). *Our future ready process.* Discovering Futures. Building Foundations. https://www.smartfutures.org/

Pitrone, R. & Taylor, S. (2018). CEISMC year in review 2018 report. Georgia Tech. https://issuu.com/ceismc/docs/ceismc_2018_year_in_review_020419?e=35052700/68279616

President's Council of Advisors on Science and Technology (2012, February). Report to the President, engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering and mathematics. https://files.eric.ed.gov/fulltext/ED541511.pdf

Rozek, C. S., Svoboda, R. C., Harackiewicz, J. M., Hulleman, C. S., & Hyde, J. S. (2017). Utility-value intervention with parents increases students' STEM preparation and career pursuit. *Proceedings of the National Academy of Sciences of the USA, 114*(5), 909-914.

Sanders, M. (2008). STEM, STEM Education, STEMmania. *The Technology Teacher.* https://vtechworks.lib.vt.edu/bitstream/handle/10919/51616/STEMmania.pdf?s

Seginer, R. (1983, January). Parents' educational expectations and children's academic achievements: A literature review. *Merrill-Palmer Quarterly, 29*(1), 1-23.

SelectGeorgia (n.d.). Fortune 500 and Fortune 1000 Georgia and Metro Atlanta Rankings 2019. https://www.selectgeorgia.com/documents/370/Fortune_500_Pub_Aug2019_zTMagiX.pdf

STEM/STEAM Georgia (2018a, September). *Implementation of STEM/STEAM in Georgia shows promising results.* http://www.stemgeorgia.org/wp-content/uploads/2018/10/GaDOE-STEM-Brief_September-2018_Mathematics-Achievement.pdf

STEM/STEAM Georgia (2018b, October). *STEM/STEAM in Georgia.* http://www.stemgeorgia.org/wp-content/uploads/2018/10/STEM_STEAM-in-Georgia.pdf

Stych, A. (2017, September 27). *Tech companies pledge $300M to STEM education.* Bizjournals. https://www.bizjournals.com/bizwomen/news/latest-news/2017/09/major-tech-companies-pledge-300m-to-stem-education.html?page=all

TAG Education Collaborative. (n.d.). *Georgia STEM Day.* https://www.tagedonline.org/programs/georgia-stem-day/page/4/

Terry College of Business. (n.d.). *Full-Time MBA Program.* https://www.terry.uga.edu/mba/fulltime/STEM.html

United States Bureau of Labor Statistics (USBLS). (2012). Options for defining STEM (Science, Technology, Engineering, and Mathematics) occupations under the 2010 Standard Occupational Classification (SOC) system. https://www.bls.gov/soc/Attachment_A_STEM.pdf

United States Bureau of Labor Statistics (USBLS). (2020, March). *Employment situation summary.* https://www.bls.gov/news.release/empsit.nr0.htm

United States Census Bureau (USCB). (2014, July 10). *Census bureau reports majority of STEM college graduates do not work in STEM occupations.* https://www.census.gov/newsroom/press-releases/2014/cb14-130.html

United States Department of Education (USDE). (2018, November). *A Leak in the STEM Pipeline: Taking Algebra Early.* https://www2.ed.gov/datastory/stem/algebra/index.html#data-story-title

United States Department of Labor (USDOL), O*NET OnLine. (n.d.). Browse bright outlook occupations. https://www.onetonline.org/find/bright?b=1&g=Go

University of Alabama System (UAS). (n.d.). *STEM programs introduce students in rural Alabama to career possibilities*. http://uasystem.edu/news/2019/03/stem-programs-introduce-students-in-rural-alabama-to-career-possibilities/

Watters, J. J., & Diezmann, C. M. (2013). Community partnerships for fostering student interest and engagement in STEM. *Journal of STEM Education, 14*(2), 47-55.

Weber, K. (2011). Role models and informal STEM-related activities positively impact female interest in STEM. *Technology and Engineering Teacher,* November, 18-21.

White, E., & Shakibnia, A. F. (2018). State of STEM: Defining the landscape to determine high-impact pathways for the future workforce. In *Proceedings of the Interdisciplinary STEM Teaching and Learning Conference* (Vol. 3, No. 1, p. 4).

Will, M. (January 23, 2018). *Need a STEM teacher? This district trains its own. Education Week.* https://www.edweek.org/ew/articles/2018/01/24/need-a-stem-teacher-this-district-trains.html

Winberg, C., Adendorff, H., Bozalek, V., Conana, H., Pallitt, N., Wolff, K., Olsson, T., & Roxa, T. (2018). Learning to teach STEM disciplines in higher education: A critical review of the literature. *Teaching in Higher Education: Critical Perspectives, 24*(8), 930-947.

Xue, Y., & Larson, R.C. (2015). STEM crisis or STEM surplus? Yes and yes. *Monthly Labor Review*. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5800410/pdf/nihms913455.pdf

Yamamoto, Y., & Holloway. SD (2010). Parental expectations and children's academic performance in sociocultural context. *Education Psychology Review, 22,* 189-214.