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School administrators’ awareness of parental STEM knowledge, strategies to promote STEM knowledge, and student STEM preparation

Sandy Watson, Omah M. Williams-Duncan, and Michelle L. Peters

University of Houston-Clear Lake, TX, USA

ABSTRACT
Background: The perceptions K-12 school administrators hold of parental STEM awareness, strategies to promote STEM awareness, and student STEM preparation are critical as these are the individuals who must make significant decisions regarding STEM curricula, STEM programming and funding, and STEM school reform.

Purpose: The present research study analyzed school administrators’ perceptions of their district’s or school’s parental STEM awareness, strategies to promote STEM awareness, and student STEM preparation.

Sample: A purposeful sample of 196 Texas administrators provided responses to the STEM Awareness Community Survey (SACS).

Design and Methods: The research applied a mixed-methods design, including quantitative and qualitative data collected through a questionnaire.

Results: Findings indicated that 71% of principals and 36% of superintendents believed K-12 parents to be uninformed about STEM (including STEM awareness in general). In particular, K-12 administrators voiced concerns that parents were not aware of: (1) available school related STEM opportunities for their children; (2) the importance of engaging in STEM with their children; and (3) the scope of preparation needed to prepare their children for STEM related careers.

Conclusion: This study’s findings demonstrate a need for increased STEM awareness among parents of K-12 students and that school administrators lack knowledge regarding strategies to improve STEM awareness and student preparation for and success in STEM careers and college, which has negative implications for STEM teachers, students, and parents.

Introduction

STEM, an acronym created by the National Science Foundation in 2000, is a curriculum that encompasses and often integrates the four disciplines of science, technology, engineering, and mathematics. While the United States (U.S.) has long been considered a STEM leader, it has had difficulty maintaining its edge among other nations primarily due to the lack of interest in STEM and STEM careers and lack of achievement in STEM among K-12 students. Alarmingly, according to Gonzalez and Kuenzi (2012), only 16% of U.S. high school students consider a STEM career and are proficient in mathematics; 57%
of freshmen who entered high school with a STEM interest lose that interest before graduation; there are 8.65 million U.S. STEM professional job vacancies; and, there is a significant shortage of skilled U.S. STEM workers (600,000). In addition, many STEM industries have reported that those applying for positions do not have the required skillsets to be successful in those positions (National Research Council 2011). The lack of STEM professionals does not bode well for a growing US economy and global competitiveness (Augustine 2005; Rodger.W 2013; Grubbs 2014; Keefe 2010), and has negative implications for ensuring national security (National Academy of Sciences, National Academy of Engineering & Institute of Medicine 2010; President’s Council of Advisors on Science and Technology (PCAST) 2012). Therefore, researchers and STEM professionals are called to consider STEM principles within the Next Generation Science Standards (NGSS), complete studies and form committees for the purposes of enacting significant change to current K-12 education systems’ current trajectories (National Research Council 2007; National Science Board 2010; National Academy of Sciences, National Academy of Engineering & Institute of Medicine 2010).

The U.S. federal government and state governments have invested substantial funds toward advancing STEM education (Tofel-Grehl and Callahan 2014). Such federal and state funds provide means for investigating STEM-related challenges gleaned from research studies, reports, and reform efforts (America COMPETES Act 2007; National Research Council 2007; President’s Council of Advisors on Science and Technology (PCAST) 2012). While current work has uncovered severe shortages of US STEM professionals and students in STEM career pipelines (Seymour 2002; Stearns et al. 2012), more researchers have identified specific needs for implementing STEM within primary and secondary school environments and alignment with STEM principles as featured in the NGSS.

The need for STEM in K-12 schools

School leaders and educational managers (e.g. principals and superintendents) of schools, have responded to the shortages of qualified individuals entering STEM fields by responding to community stakeholders and implementing a variety of STEM-related K-12 school initiatives (Blau and Weinberg 2017; Krishnamurthi, Ballard, and Noam 2014; Brian, Darrel Sandall, and Walton 2018; Seymour 2002). These endeavours include creating schools with STEM foci; adopting STEM-aligned curricula for use in non-STEM schools; offering advanced STEM courses; introducing STEM-related curricula and programs earlier during the educational timeline (early childhood/kindergarten); collaborating with STEM professionals, those who work and lead STEM-based companies, via advisory committees; incorporating STEM pedagogical strategies such as inquiry and the use of claims, evidence, and reasoning; providing additional extracurricular STEM activities at all school levels to include coding for elementary grades, STEM summer camps, and robotics during afterschool programs, etc. These endeavors originated from collaborative efforts among stakeholders, school-based committees consisting of parents, business leaders, school leaders, and expert researchers within the STEM community. In spite of all of these measures, U.S. students are still unlikely to complete requisite certification or degree programs for initial entry into STEM related careers. Hence, the U.S. STEM workforce continues to be underprepared and lacking, causing researchers to design studies about student persistence and completion levels in STEM majors.
The need for post-secondary STEM program graduates

The U.S. economy needs K-12 students continually entering, persisting, and completing post-secondary STEM programs (Seymour 2002). Without higher student STEM major completion rates, the U.S. STEM workforce will continue to decline (Rodger.W 2013; National Academy of Sciences, National Academy of Engineering & Institute of Medicine 2010; Public; Agenda 2010; President’s Council of Advisors on Science and Technology (PCAST) 2012; Brian, Darrel Sandall, and Walton 2018). Additionally, U.S. created STEM-innovations will continue to falter, along with global economic productivity (Rodger.W 2013; National Academy of Sciences, National Academy of Engineering & Institute of Medicine 2010). Interest in, curiosity about, and awareness of STEM careers and functions undergird student completion rates along with many other factors. Researchers notice the importance K-12 STEM awareness has when students initially enter school-level programs.

Researchers are working to learn the impacts of many K-12 STEM programs since school leaders and community members have responded to the challenge of increasing more qualified STEM professionals. These community members and school personnel collaborate to implement K-12 STEM programs and develop STEM policy and practices. Krishnamurthi, Ballard, and Noam (2014) presented the effects of growing student curiosity, confidence, and skills in STEM through implementation of a variety of K-12 school-based STEM programs. These researchers noted that STEM summer camps and afterschool programs, along with integrating STEM-based curricula during the regular school day have positive effects on student STEM career orientation (Reinhold, Holzberger, and Seidel 2018; Falk et al. 2016). STEM career orientation motivates students to major in STEM fields at the collegiate level. Effective elementary and secondary STEM programs are also being found to increase student confidence and persistence; participating students recall such programs as they matriculate through collegiate STEM majors (Brown et al. 2016; Sithole et al. 2017; Sondergeld, Johnson, and Walton 2016). Students cite fun experinces and feelings of being able to make a difference or change the world. While these positive effects show promise in changing the STEM professional landscape, researchers are also considering why students choose to leave STEM collegiate programs (Ball et al. 2017; Paul., Lemay, and Doleck 2018).

Elementary and Secondary STEM programs have long-term impacts on students. The experiences shape career orientations, allowing students to connect academic content to STEM discipline practices via instructional strategies like problem-based instruction (Rodger.W 2013; Krishnamurthi, Ballard, and Noam 2014; Reinhold, Holzberger, and Seidel 2018; Sahin, Ekmekci, and Waxman 2018). These STEM-specific instructional strategies in K-12 settings shape student interest and the definion of STEM. However, parents and community members affected by larger community oriented STEM education strategies have differing impressions of STEM. STEM is defined as separate subjects or practices in the domains of Science, Technology, Engineering, and Mathematics (Rodger.W 2013). Consequently, STEM awareness among varying groups has inconsistencies. Let us now consider those inconsistent definitions, as the need for STEM allows implementation of STEM programs in elementary and secondary school settings.
The need for STEM awareness

STEM awareness varies across community members (including parents), school leadership and STEM professionals. While most community members define STEM by reciting the academic subjects that comprise the acronym Science, Technology, Engineering, and Mathematics, researchers debate the level of integration of these disciplines as a definition of STEM literacy (Breiner et al. 2012; English 2016; Brian, Darrel Sandall, and Walton 2018; Sanders 2009; Zollman 2012) or the exclusion of one or more disciplines (Brown 2012; Rodger.W 2013) within a STEM curriculum or program. To that end, many studies include an introduction about STEM awareness, signaling the author’s awareness of STEM. Those beginning statements will often suggest a need to operationalize STEM and imply that perceived definitions shape the execution of STEM programs in school settings (Brown et al. 2011; Harris Interactive 2011; Keefe 2010; Sondergeld, Johnson, and Walten 2016).

Levels of STEM awareness are gateways to varied opportunities for schools and K-12 students. As STEM awareness levels vary, so do the types and content of STEM curriculum and experiences. Rodger.W (2013) reviewed various stances of STEM awareness in the text, The Case for STEM Education: Challenges and Opportunities. He identified and defined nine different levels of STEM awareness which are listed as follows:

- Single-discipline reference
- STEM as reference for Science and Mathematics
- Separate Science disciplines that incorporate other disciplines
- Separate disciplines (also called silos)
- Science and Mathematics connected by Technology or Engineering programs
- Coordination across disciplines
- Combination of two or three disciplines
- Integration across disciplines
- STEM as a transdisciplinary course or program

Rodger.W (2013) designed his text for school leaders. School leadership STEM awareness, which by proximity, influences student awareness of STEM, is a topic of concern because educators affect school programmatic policy and content. Leadership’s management of school-based STEM programs is a product of their awareness levels (Brown et al. 2012). Bybee’s stated purpose of his text is to influence STEM purpose, policy, program, and practices at the school and community levels, by educating school leaders and parents about the history and varied perspectives of STEM.

Community members (including parents) and school leaders have varied awareness levels of STEM that shape the implementation and substance of such programs in schools (Brown et al. 2012; Falk et al. 2016; Keefe 2010; Sondergeld, Johnson, and Walten 2016). This study focuses on STEM awareness levels. Unlike the research of Sondergeld, Johnson, and Walten (2016), this study examines the awareness of school leaders who influence most school or district-level STEM programs. For this study, school leaders are superintendents and principals. Parents and students are consumers of STEM programs facilitated by school leaders. Hence, school level program success or failure hinges on parental
support, as influenced by STEM awareness. In short, as parents encourage their kids to participate in such STEM programs, the chances of STEM program success increase.

**STEM awareness of K-12 parents**

It is critical that school leaders have awareness of what K-12 parents know and do not know about their children’s STEM education so that the leaders might address parental gaps in knowledge via information sessions. The impact of parental involvement and parental academic expectations on their children’s education has long been documented (Alcena 2014; Barnard 2004; Benner, Boyle, and Sadler 2016; Jeynes 2016). The tremendous role parents can play in the learning experiences of their children is not surprising since children spend, on average, 80% of their waking hours with their parents (when not in school) (LIFE Center 2005). In addition, children’s attitudes toward science are developed at young ages (5–11), when they are most apt to be spending the most time with parents (Pell and Jarvis 2001). From homework help to attendance at school events to volunteering in various capacities in their children’s schools to influencing children’s career paths, parental involvement has positively impacted children’s educational success. Parental involvement in K-12 schools has also been linked to increased grade-level promotion, greater on-time graduation rates, more participation in advanced courses, and lower school drop-out rates (Barnard 2004). In addition, the tendency for ‘occupational inheritance’ has been observed in STEM careers (e.g., children of doctors become doctors), demonstrating the influence parents have on their children’s career choices (Gubler et al. 2017). Parental involvement in their children’s education has also been connected to student self-efficacy (Bandura 1994), students’ sense of mastery orientation (the perception that one has control over their own educational outcomes) (Gonzalez, Holbein, and Quilter 2002), and children’s school engagement (Park and Holloway 2017).

In an attempt to determine factors that prepare and inspire students to pursue STEM related degrees, the Microsoft Corporation commissioned a national study of the perceptions/attitudes of STEM education held by parents (2017). Findings revealed: (1) while 93% of parent participants believe STEM education is critical in the U.S., only 49% felt it should be a top priority; (2) the parents who felt STEM education should be a top priority want the U.S. to remain globally competitive (53%) and to produce a generation of innovators (51%); 36% indicated they believe STEM should be a top priority because they want their children to have well-paying and/or fulfilling careers. However, according to Microsoft’s study, only 24% of parent participants indicated willingness to put forth the necessary funds to help their children successfully complete their science and mathematics courses in school.

According to McClure et al. (2017), parents begin thinking about encouraging their children to consider STEM careers while their children are still in early childhood, but lack confidence in STEM knowledge and even experience anxiety about STEM topics, which can be transferred to their children and can affect how their children learn science in K-12 (Education Business Weekly, 2017) and/or can be the reason why students ‘leak’ from the STEM pipeline.

Gonyea (2017) found that parental ($n = 227$) STEM awareness was a predictor of student enrollment in advanced STEM courses at a large public high school in Middle Tennessee. Students of parents who scored higher in the areas of attitude and knowledge associated with STEM on the Parental STEM Awareness Survey demonstrated a higher
probability of enrolling in advanced STEM courses (Gonyea 2017). Mihelich et al. (2016) examined the attitudes toward science among students and parents and found that when parents hold positive perceptions of science, their children are more likely to also hold positive attitudes of science.

All of these findings illustrate the vast impact parents have on children’s STEM educational successes, career track choices (STEM or otherwise), and perseverance in STEM and the critical need for school administrators to be cognizant of their district or school’s parental STEM awareness levels. These conclusions also demonstrate a need for further study of STEM education in the broader social context that involves parents, teachers, and administrators. Before revealing the methods of this study about school leaders’ knowledge of parental awareness of STEM, an introduction about present STEM awareness strategies follows.

Currently identified STEM awareness strategies

Several strategies connected with STEM-based companies and academic research practices, influence educators’ STEM awareness. These strategies may be categorized as curricular focused, teacher/student focused, whole-school focused, and community focused. Researchers question the effectiveness of these strategies on educators’ and parents’ STEM awareness. Specifically, researchers wonder if such strategies positively influence educators’ and parents’ STEM awareness.

Curriculum focused STEM awareness strategies

Strategies to increase K-12 lessons about STEM-based principles, practices and skills are curriculum focused STEM awareness strategies. Examples include educator adaptation and alignment of lessons to the Next Generation Science Standards and STEM-company development, influence, and dissemination of STEM-field aligned lessons. These approaches mainly impact educator STEM-awareness, with parental STEM-awareness being impacted by whole-school and community focused impact strategies.

Curriculum, comprised of standards for student expectations, indicate what should be taught in classroom settings (DeBoer 2019). Educators plan classroom experiences by reviewing and aligning developed lessons with curriculum. STEM curriculum consists of state or national standards related to disciplinary content, and principles and practices by those in STEM industry. Such principles and practices inform and prepare students for STEM fields. The Next Generation Science Standards (NGSS) includes a domain called the Engineering, Technology, and Applications of Science (ETS) and a sub-set of performance expectations called Science and Engineering Practices. The NGSS were developed by educators from K-12 and higher education, along with practitioners from STEM company settings. When educators align their lessons with performance expectations within the Science and Engineering Practices or ETS domain, they are implementing expectations set forth by the STEM community. Further, NGSS aligned lessons are designed to increase student STEM awareness by facilitating experiences that occur in STEM fields (Smith and Nadleson 2017), providing students with memories that influence their career paths (Krishnamurthi, Ballard, and Noam 2014). Similar statements are made about STEM-company produced lessons when researchers study their impacts on students. For
example, researchers Kennedy and Odell (2014) noted how implementation of such STEM lessons informed participating students and teachers about STEM careers. Lesson alignment to STEM principles and practices is only one facet of influencing student STEM awareness. Additionally, parental STEM awareness is not the subject of these studies. Discussing teacher training to implement STEM lessons for the purposes of student participation and the sequential impact on student STEM awareness follows.

**Teacher/Student focused STEM awareness strategies**

Professional development for teachers and informative interactions for students in K-12 settings primarily comprise approaches to increase teacher and student STEM awareness. Additionally, when STEM companies generate elementary, secondary and post-secondary STEM resources, they impact teacher/student STEM awareness (Krishnamurthi, Ballard, and Noam 2014). Training informs teachers how to implement STEM resources or programs. As teacher STEM awareness is impacted by the trainer, student STEM awareness is subsequently influenced. Zollman (2012) advanced educator and classroom strategies that attend to increasing STEM awareness. The strategies included integrating STEM disciplines, emphasizing problem solving, investigation and analysis of scientific questions, and deliberately focusing on the value of STEM. Nurturing student belief/identity as STEM citizens is also mentioned, along with a focus on alignment to educational learning theory. For educators, Zollman (2012) described how Bloom’s taxonomy may be aligned to STEM literacy in Bloom’s Digital Taxonomy, to emphasize the power of discipline integrations to influence economic, societal, and personal needs. Teacher implementation choices and confidence levels (Sadler et al. 2012) along with access to requisite materials and autonomy are factors that effect information transmission and program implementation after STEM-based professional development (Brown et al. 2011). Consequently, teacher STEM awareness influences student and parental STEM awareness to varying degrees (Brown et al. 2011; Philip et al. 2012). Tracking changes in student and parental STEM awareness was not the subject of these studies. As school leaders and parental STEM awareness levels are the focus of this study, a closer review of influences of school leader and parental STEM awareness occurs when considering whole-school and community focused STEM awareness strategies.

**Whole-school focused STEM awareness strategies**

Influencing STEM awareness to encourage teacher, parent, and student participation in whole-school programs requires creative, all-inclusive strategies. On-line, face-to-face and hands-on, activity laden experiences, are a few implemented models. Program evaluators studying the development of STEM-schools, middle and secondary schools implementing STEM-based instructional strategies and curriculum, listed types of whole-school focused strategies designed to effect STEM awareness. The reports listed such strategies as disseminating paper-based infographics (e.g., pamphlets and flyers), displaying and posting on-line school recruitment materials (Kennedy and Odell 2014) showcasing student generated class and cap-stone projects (Kennedy and Odell 2014; Krishnamurthi et al. 2014) hosting open house or meet-theeacher sessions, and coordinating with recruiters from post-secondary STEM programs (Krishnamurthi, Ballard, and Noam 2014). As
secondary school leaders facilitate these occurrences to attract and maintain parental support and corporate collaboration, these strategies also impact parental STEM awareness. However, interactions between these strategies and parental STEM awareness was not the subject of these reports. Parental STEM awareness is influenced by other factors, such as personal profession and efforts by corporate or government agencies (Wang and Degol 2013). Parents, like teachers, students, and school leaders are part of the community targeted by STEM-based corporations to increase a viable workforce.

**Community focused STEM awareness strategies**

STEM companies, with schools, implement a variety of community focused STEM awareness strategies to influence parents and many other types of community members’ STEM awareness. Such strategies include producing television commercials, sponsoring middle and secondary STEM schools and STEM competitions, surveying parents, and collaboration on STEM education policy projects. STEM-company sponsorships can involve the provision of funding and STEM employee services like providing expert advice and student mentorship. Company produced STEM-awareness commercials succinctly describe STEM jobs and disciplines, product innovations, and advantages of supporting STEM-fields. Company sponsorships of STEM schools and competitions demonstrate company interest in educational programs and graduation outcomes ideally connected with STEM-based degrees, majors and entry level positions (Sonderegeld, Johnson, and Walten 2016). Companies effect parental STEM awareness via commercials and sponsorships; parents are likely to remember presented information when encouraging and considering potential career pathways for their children (Wang and Degol 2013). School leaders, in turn, survey parents and recruit their participation on school advisory boards (Ing 2013).

STEM company goals for influencing community members, and especially parents, connect with education and financial rationale. When parental and business support for student enrollment at and experiences in STEM schools increases, cultivation of collaborators for school leaders of STEM schools and programs also increases. Knowledgable parents and business owners donate their time, services, and resources. Their cooperation reduces financial requirements for STEM programs and helps to generate ideas that potentially increase quality experiences for students. School leaders rely on the STEM awareness of parents and community members. Hence, delving into what school leaders know about the population they look to for support is key.

**Research purpose and questions**

The purpose of this mixed methods study was to assess the beliefs of K-12 Texas school school leaders regarding K-12 parental STEM awareness and to elicit their suggestions for promoting STEM awareness among parents. The following research questions were addressed in this study:

Research Question 1: What do K-12 school leaders believe regarding STEM awareness among parents and STEM resources?
Research Question 2: What do K-12 school leaders believe regarding strategies that could be implemented in their districts/schools to improve STEM awareness among parents?

Research Question 3: What do K-12 school leaders believe regarding the preparation of students for success in college and careers in their schools/districts?

Research Question 4: What do K-12 school leaders believe regarding the strategies they think could be implemented in their schools/districts to improve student preparation and success in STEM careers and college?

Participants

For the purposes of this study, school leaders are defined as principals and superintendents of elementary and secondary schools. In the United States, principals serve as the primary leaders of individual schools while superintendents oversee all of the schools in a particular district. One district may contain multiple schools, thus the number of principals will far outnumber that of superintendents. Principals manage single schools to ensure safety and academic instruction of all enrolled students, while superintendents manage all schools in their districts. In the state of Texas, there are a total of 1,200 public school districts, and 8,759 public schools serving a total of 5,385,012 public school students (Profile on Texas Education 2020). Of those schools, 3,240 are high schools, 2,181 are middle schools, and the remainder are elementary schools. Texas schools include urban and rural locations. The primary difference between the two in the state of Texas is that urban schools typically serve minority students from lower income families who have limited English language proficiencies while rural schools are disproportionately white but can suffer significant poverty rates.

Principals

The majority of the principals were female (61.5%, n = 99), while the remaining were male (38.5%, n = 62). The racial/ethnic representation of principals were as follows: 10.6% African American/Black (n = 17), 60.0% Caucasian/White (n = 96), 26.8% Hispanic/Latino (n = 43), and 2.5% two or more races (n = 4). Principals also reported average years of experience as administrators to be 18 and average years of educator experience to be 33. Finally, when principals were queried about the highest degree they held, 10.6% responded with Doctor of Philosophy (Ph.D.) or Doctor of Education (Ed.D.), 6.3% with Educational Specialist (Ed.S.), 82.5% with either a Master of Arts or Master of Science (MA/MS), and 0.6% identified as holding a Bachelor of Arts or Bachelor of Science BA/BS degree. In the United States, educational degrees are usually obtained in the following order: Bachelor of Science or Bachelor of Arts, Master of Science or Master of Arts, Educational Specialist, Doctor of Education or Doctor of Philosophy.

Superintendents

The majority of superintendents were female (64.3%, n = 9), while the remaining were male (35.7%, n = 5). The racial/ethnic representation of superintendents were as
follows: 21.4% African American/Black \((n = 3)\), and 78.6% Caucasian/White \((n = 11)\). Superintendents also reported 25 average years of experience as administrators and 40 average years of educator experience (because superintendents typically start out their educational careers as teachers, then move into administration at the building level before moving on to district level administration, spanning many years of educational service). Finally, when superintendents were queried about the highest degree they held, 23.1% responded with Ph.D./Ed.D., 15.4% with Ed.S., and, 61.5% with MA/MS.

**Instrumentation**

The *STEM Awareness Community Survey (SACS)* was developed by Sondergeld, Johnson, and Walten (2016) using Liu’s (2010) framework for the creation of instruments utilized to assess affective variables in science education. A convenience sample of 72 participants completed the initial pilot survey: 39 K-12 teachers, 17 higher education faculty, and 16 business community members. For field testing purposes, a sample size of 72 is appropriate for this instrument since a 5-point Likert scale was used and the goal is to have a minimum of 10 participants per scale category, thus making 50 the minimum number of participants acceptable for this situation (Liu 2010). The 39-item survey consists of a 4-point Likert scale \((1 = \text{Strongly Disagree}, 2 = \text{Disagree}, 3 = \text{Agree}, 4 = \text{Strongly Agree})\) and four subscales: (a) Industry Engagement in STEM Education \((8\text{-items})\), (b) STEM Awareness and Resources \((13\text{-items})\), (c) Preparation of Students for Success in College & Careers \((6\text{-items})\), and (d) Regional STEM Careers and Workforce \((12\text{-items})\). For purposes of this study, only data collected from the STEM Awareness and Resources subscale is reported (Cronbach’s alpha = .81).

**Data collection & analysis**

Following Institutional Review Board IRB permission (university committee that ensures research studies are ethical), *SACS* was emailed to K-12 Texas school administrators listed in a Texas Education Agency (TEA) administrators’ database via Survey Monkey. The database included all principals in all public schools in the state of Texas. In addition to a link to the survey, the email invitation included the timeline for completing the survey, a survey cover letter, and instructions regarding the data-collection process. Follow up solicitations were sent three additional times to administrators in the database to prompt them to complete the survey. Data submitted by the participants was considered usable if the respondents completed at least one full component of the survey. All quantitative data were analyzed using IBM SPSS. Quantitative data analysis consisted of the use of descriptive statistics in an attempt to elicit demographic information about the survey respondents. To examine STEM resources and STEM awareness \((Q1)\), descriptive statistics were calculated for each of the Likert-scaled sub-statements \((13\text{-total})\) to determine frequency of response selection.

The responses to research questions two and four \((Q2 \text{ and } Q4)\) were open-ended in nature and thus qualitative methodology was utilized to analyze and code responses for recurring terms and concepts. Qualitative data analysis was initiated with data organization and interpretation utilizing MAXQDA analytics software. The researchers read and re-
read all qualitative responses provided by participants to search for the emergence of categories of meaning. Once the work of generating categories and themes from the responses from questions two and four (Q2 and Q4) were initially completed, the identified categories and themes were coded using MAXQDA. Included in this phase was a period in which the data were reduced according to relevancy, eliminating digressive responses and simplifying language. Peer debriefing was accomplished by having two researchers independently code the open-ended responses and discuss findings.

**Findings**

The scope of the SACS survey that was utilized in this research study resulted in a large expanse of data, too large to address in this paper alone. Thus, the components related to K-12 administrators’ beliefs concerning K-12 parental STEM awareness (Q1, sub-question 3), STEM school district awareness strategies (Q2), and beliefs and strategies related to student STEM education preparation and career success (Q3-4) are the primary foci of this paper. Table 1 depicts the comparison of collapsed responses of principals and superintendents to research question 1’s (Q1: STEM Awareness and Resources) 13 sub-questions.

Table 2 depicts the comparison of collapsed responses of principals and superintendents to research question 3’s (Q3: Preparation of Students for Success in Colleges and Careers) 6 sub-questions.

**Table 1. Comparison of collapsed responses on STEM Awareness and resources (%).**

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Disagree/Strongly Disagree</th>
<th>Agree/Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. My school district understands the importance of STEM education.</td>
<td>Superintendent: 0.0</td>
<td>Principal: 100.0</td>
</tr>
<tr>
<td>2. The schools in this district understand the importance of STEM education.</td>
<td>Superintendent: 6.8</td>
<td>Principal: 85.9</td>
</tr>
<tr>
<td>3. Parents in this district understand the importance of STEM education.</td>
<td>Superintendent: 0.0</td>
<td>Principal: 100.0</td>
</tr>
<tr>
<td>4. More work needs to be completed to spread awareness of STEM education.</td>
<td>Superintendent: 9.4</td>
<td>Principal: 74.38</td>
</tr>
<tr>
<td>5. STEM skills are integral to student success today.</td>
<td>Superintendent: 14.3</td>
<td>Principal: 71.4</td>
</tr>
<tr>
<td>6. Increasing the STEM talent pool is necessary for economic vitality.</td>
<td>Superintendent: 35.6</td>
<td>Principal: 36.3</td>
</tr>
<tr>
<td>7. Students with postsecondary education are more likely to secure a career in a STEM field.</td>
<td>Superintendent: 7.2</td>
<td>Principal: 78.6</td>
</tr>
<tr>
<td>8. There are colleges and/or universities and/or community colleges that offer scholarships for students to pursue STEM degrees in my region.</td>
<td>Superintendent: 2.5</td>
<td>Principal: 89.4</td>
</tr>
<tr>
<td>9. There are STEM education Web sites available for this region that include activities for teachers and students.</td>
<td>Superintendent: 1.9</td>
<td>Principal: 92.5</td>
</tr>
<tr>
<td>10. Information on regional STEM career opportunities is available online.</td>
<td>Superintendent: 1.2</td>
<td>Principal: 93.2</td>
</tr>
<tr>
<td>11. Local organizations recruit STEM talent online.</td>
<td>Superintendent: 0.0</td>
<td>Principal: 71.2</td>
</tr>
<tr>
<td>12. Information related to STEM opportunities in my region is available online.</td>
<td>Superintendent: 1.9</td>
<td>Principal: 83.2</td>
</tr>
<tr>
<td>13. There are other STEM online tools available to this district.</td>
<td>Superintendent: 28.6</td>
<td>Principal: 57.1</td>
</tr>
<tr>
<td></td>
<td>Principal: 5.0</td>
<td>Principal: 63.1</td>
</tr>
</tbody>
</table>
Table 2. Comparison of collapsed responses on preparation of students for success in college and careers (%).

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Superintendents</th>
<th>Principal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Students in this district are prepared by K-12 schools to be successful in postsecondary study (2- or 4-year colleges or universities and technical programs).</td>
<td>7.1 Strongly Disagree</td>
<td>78.6 Agree</td>
</tr>
<tr>
<td>2. Students in this district are knowledgeable about the STEM careers that will be in high demand when they graduate.</td>
<td>14.3 Strongly Disagree</td>
<td>50.0 Agree</td>
</tr>
<tr>
<td>3. The K-12 public schools in this district effectively teach students STEM knowledge and skills.</td>
<td>14.3 Strongly Disagree</td>
<td>64.3 Agree</td>
</tr>
<tr>
<td>4. The state standardized tests used in this district’s K-12 schools adequately assess STEM knowledge and skills.</td>
<td>64.3 Strongly Disagree</td>
<td>7.1 Agree</td>
</tr>
<tr>
<td>5. The K-12 schools in this district prepare students who are critical thinkers and problem solvers.</td>
<td>0.0 Strongly Disagree</td>
<td>78.6 Agree</td>
</tr>
<tr>
<td>6. Community partners (e.g. business and higher education) are engaged in making K-12 STEM education more relevant through providing real-world connections in this district.</td>
<td>35.7 Strongly Disagree</td>
<td>42.9 Agree</td>
</tr>
</tbody>
</table>

Parental STEM awareness

Administrator participants demonstrated 38.5% overall agreement with the statement ‘parents in my district understand the importance of STEM education,’ but a perceptual incongruence was detected between superintendents and principals, with 71.4% of superintendents agreeing and only 36.3% of principals agreeing.

In addition, when asked to respond to research question 2 (Q2: What other strategies do you believe could be implemented in your district to improve STEM awareness?) 11 participants indicated the need for STEM education for parents. Specifically, the following themes emerged regarding parental awareness of STEM (Q2):

- More understandable information concerning STEM needs to be made available to parents.
- More information about STEM academies and their benefits to students needs to be made available to parents.
- More information concerning STEM careers needs to be offered to parents.
- The need to implement extracurricular STEM events that promote STEM careers with incentives for parents to attend.
- Information about why STEM is important should be available to parents.
- Parent open houses pertaining to STEM should take place.
- The need for a district STEM advisory council with parental involvement.
- Parental outreach in general concerning STEM.
- Parental outreach concerning the need for STEM clubs and courses.
- Provide parent STEM education nights and opportunities for parents to explore STEM careers.
- More information about STEM classes and STEM careers made available to parents.
- Potential STEM employers invited to speak to parents.

While many suggestions were offered in response to research two (Q2: What other strategies do you believe could be implemented in your district to improve STEM
awareness?), 15 out of 140 (56 participants skipped this question) responses were alarming ‘I don’t know’ ‘I’m not sure’ ‘N/A’ reactions.

Regarding research question 3 (Q3: What do K-12 school leaders believe regarding the preparation of students for success in college and careers in their schools/districts?), 78.6% of superintendents and 73.9% of principals agreed that students in their schools and districts are adequately prepared to be successful in postsecondary STEM study. However, both superintendents and principals were less confident that their students will be knowledgeable of potential high demand STEM careers upon their graduations (50% superintendents and 52.8% principals strongly agreed). Regarding the belief that K-12 schools in their district effectively teach STEM skills and knowledge, 64.3% of superintendents agreed or strongly agreed while 48.4% of principals did. Interestingly, neither superintendents nor principals believed state standardized assessments adequately assess STEM knowledge and skills, with 64.3% of superintendents and 48.4% of principals disagreeing or strongly disagreeing that standardized assessments adequately evaluate STEM knowledge and skills. Further, both superintendents (78.6%) and principals (60.9%) agreed or strongly agreed that the schools in their district prepare students who are critical thinkers and problem solvers. Finally, the numbers were less conclusive regarding whether or not community partners are engaged in making K-12 STEM education more relevant through providing real-world connections in their districts.

Regarding research question 4 (Q4: What strategies do you believe could be implemented in your district to improve student preparation and success in STEM careers and college?), several participants offered suggestions that involved promoting STEM awareness among K-12 parents. Specifically, the following themes emerged regarding parents and student preparation and success in STEM careers and college:

- K-12 parental understanding of STEM and STEM education is inadequate.
- Parents are unaware of STEM opportunities available to their children.
- Parents and children need to connect more by engaging in STEM projects in their homes.
- STEM information needs to be made more explicit to parents.

Discussion

Regarding K-12 school administrators’ beliefs of parental STEM awareness, the findings of this study are concerning, as 38.5% of administrator respondents (superintendents and principals collectively) agreed that parents in their districts understood the importance of STEM education (71.4% of superintendents agreed while only 36.3% of principals agreed). The lack of perceptual congruence between administrators’ groups (superintendent and principal) is problematic.

One reason for the incongruency could be that superintendents often work in isolation from principals, protected from interference from school level faculty, administrators, and parents (Blase and Anderson 1995), and many operate in top-down communication styles, often serving to maintain the status quo (Kowalski 2001). Thus, it would be understandable that superintendents might hold inaccurate views of parental awareness of STEM, since they (superintendents) are often distant from what is happening in the schools in their districts and have limited, if any, interactions with parents. In addition, this
incongruency points to a lack of communication between school principals and district superintendents. Since principals have the most frequent contact with parents and students, it stands to reason that they would have the most accurate perceptions of parental awareness levels. Thus, principals and superintendents must improve their communication with one another to discourage the formation of false perceptions that could negatively impact students (superintendents believing that parents are STEM aware and thus not funding programs or initiating information sessions that could improve their awareness, for example).

The literature is rife with studies that prove the critical role parents play in their children’s STEM educational successes, career track choices (STEM or otherwise), and perseverance in STEM. Hall et al. (2011) conducted a study in which parents were asked to rate their knowledge of STEM career fields on a scale of 1 to 5, where a rating of 1 meant ‘very little knowledge’ and a rating of 5 meant ‘a great deal of knowledge’. Their findings indicated that only 15.4% felt they were very knowledgeable of STEM careers. Most (37.4%) fell in the middle range, and 11% admitted very little awareness of STEM careers. However, the findings of Hall et al. (2011) do not assess parents’ STEM accrual career knowledge, but only their perceived knowledge. Parents who are lacking in understanding regarding the importance of STEM education can transfer that lack of understanding upon their children, perhaps negatively impacting their children’s decisions to pursue STEM careers (McClure et al. 2017). Additionally, parental perceptions of education can impact student self-efficacy (Bandura 1994), students’ sense of mastery orientation (Gonzalez, Holbein, and Quilter 2002), and children’s school engagement (Park and Holloway 2017). Participating administrators in this study indicated a significant concern for the lack of parental STEM awareness among parents in their districts and offered numerous suggestions to address the problem.

One alarming finding of this study arose from research questions two (Q2: What other strategies do you believe could be implemented in your district to improve STEM awareness?) and four (Q4: What strategies do you believe could be implemented in your district to improve student preparation and success in STEM careers and college?). Fifteen of 140 (56 skipped the question) respondents replied to Q1 with ‘I don’t know,’ ‘I’m not sure’ or ‘N/A’ reactions while 11 of 133 (53 skipped the question) respondents replied similarly to Q4. This lack of knowledge among administrators regarding strategies to improve STEM awareness and student preparation and success in STEM careers and college indicates a profound disconnect between administrators’ beliefs regarding their own STEM awareness and their ability to demonstrate that knowledge through the identification of STEM strategies associated with the improvement of STEM awareness and with student preparation and success in STEM careers in college.

Regarding research question three (Q3: What do K-12 school leaders believe regarding the preparation of students for success in college and careers in their schools/districts?), 78.6% of superintendents and 73.9% of principals agreed that students in their schools and districts are adequately prepared to be successful in postsecondary STEM study. However, both superintendents and principals were less confident that their students would be knowledgeable of potential high demand STEM careers upon their graduations (50% superintendents and 52.8% principals agreed or strongly agreed). This finding may be explained in part by Hall et al. (2011) who determined that high school teachers are primary influencers of students’ career choices and furthermore, that high school math
and science teachers do not believe they are knowledgeable enough about scientific career fields (32.3%), information technology career fields (62.5%) or engineering career fields (61.3%). The findings of this study suggest the need for programming or initiatives related to **advancing knowledge of STEM careers among students, teachers, and parents.**

**Implications**

The STEM awareness of K-12 school administrators has implications for students, teachers, parents, the community (to include STEM industry and higher education), and the U.S. This study, as well as the literature review findings, have demonstrated that the beliefs of school administrators can impact their actions including their decisions related to curricular implementation, program offerings, and school reform efforts related to STEM education.

**Implications for students and teachers**

When administrators believe current school/district STEM curriculum and programming is inadequate, new STEM curricula and initiatives are implemented. In K-12 schools, teachers are often the first group of impacted stakeholders. These are the individuals who are responsible for executing new initiatives and therefore must often undergo additional training and professional development in preparation for implementation. Often, elementary level teachers are not confident in their STEM content knowledge and therefore can be reluctant to implement new STEM related curricula (Hammack and Ivey 2017). In addition, because teachers are evaluated based in part on student standardized test performance, it is critical to them that any new curriculum considered adequately address the educational standards they must adhere to. Any misalignment between curriculum and standards can be detrimental to student performance on standardized tests, which can negatively impact perceptions of teacher performance, which in turn can influence merit pay, tenure (if applicable) and rehiring decisions.

Conversely, when administrators are inaccurately aware of their schools and districts, or when administrators demonstrate perceptual incongruency related to a construct, negative consequences can result. For example, if superintendents and principals disagree as to the STEM awareness levels of the stakeholders in their district, with the superintendents believing the district already demonstrates high levels of STEM awareness and principals indicating that the district does not have adequate STEM awareness (as is the case in this study), principals may defer to superintendents (since they hold the power) and no initiatives or reform efforts are introduced when they are actually desperately needed.

Students are also impacted by administrators beliefs. For example, when administrators perceive current STEM curricula to be inadequate, they will make the decision to implement a different program. This change will initiate different experiences, and/or school reform efforts, where students, who are familiar and comfortable with how they have been (or have not been) learning STEM, now must adapt to a new methodology, new texts, new instructional requirements, etc. Coincidentally, parents are also impacted, yet superintendents’ and principals’ awareness of parental awareness are incongruent.
Implications for parents

This study revealed that administrators believe K-12 parental STEM awareness is lacking. The literature is clear that parental involvement and support can be critically influential to student STEM education participation and STEM career selection. If parents are unaware or unconcerned with their children’s STEM education, then their children are less likely to pursue advanced STEM courses and STEM careers. The findings of this study clearly highlighted the need for increased parental knowledge of STEM, STEM education, and STEM career opportunities. The call has been placed that explicit information relating to STEM be made available to parents, that school open houses focused on parental involvement in STEM take place, and that connections between parents and STEM professionals are critical to advance STEM awareness among parents. Parental involvement represents a critical link to community STEM awareness, as their knowledge increases, so can community STEM awareness.

Implications for the community

This study has significant implications for community STEM stakeholders, to include STEM industry and higher education. These stakeholders can no longer be uninvolved in K-12 STEM education as their very existence depends on getting students interested in STEM at younger and younger ages. When students can make a personal connection to a STEM career field, they are more likely to consider entering a STEM field themselves. Thus, industrial STEM professionals and higher education STEM professionals need to make it a priority to connect with schools and serve as mentors and role models to future STEM workers.

Implications for the U.S

As mentioned in the literature review, the U.S is experiencing a critical shortage of STEM students, workers, and professionals and this shortage has implications for national security and the global standing of the U.S. in STEM. Therefore, the STEM and STEM education initiatives offered by K-12 schools are serious undertakings that can impact whether or not students elect to pursue STEM related careers. When stakeholders (including administrators and parents, among others) are not communicating, unaware, or are misinformed regarding STEM, educational programs in STEM may not be offered, students’ STEM achievement may not be supported, and thus fewer students will excel in STEM and pursue STEM careers. Fewer students interested in STEM and STEM careers means the STEM pipeline shrinks further, leaving more and more STEM jobs unfilled, and ultimately negatively impacting U.S. national security and STEM standing in the world.

Conclusion

This study’s findings demonstrate a need for increased STEM awareness among parents of K-12 students. To address the issue, administrator participants cited the need for more opportunities for parents to participate in STEM activities with their children, more opportunities to be educated about STEM career options and the importance of STEM education, parental involvement in district-wide STEM advisory councils, opportunities to
explore STEM during summer STEM camps, etc. The literature is clear about the tremendous impact parents can have on their children’s educational experiences and career choices, and that parents who experience anxiety or lack knowledge about STEM can visit those fears upon their children, possibly resulting in those children not pursuing advanced courses in STEM or STEM-related careers.

The problematic findings concerning the lack of knowledge among administrators regarding strategies to improve STEM awareness and student preparation for and success in STEM careers and college has negative implications for STEM teachers, students, and parents. The literature indicates support, knowledge, and guidance of administrators is essential for program success. A lack of understanding of STEM strategies can also negatively impact the STEM-related decisions of administrators, which in turn can negatively impact classroom practices related to STEM. Changes to schoolroom experiences would further impact student STEM career choices. Administrators are perceived by many as instructional leaders of their districts/schools and are influential regarding the adoption of STEM programming and initiatives; therefore, the nature of the knowledge they possess associated with STEM and STEM implementation is critical to teachers, parents and students.

In sum, the data and results of this study can be beneficial to educational administrators interested in advancing effective STEM-related programs in their districts and schools. The findings gained from this study can positively impact the implementation and sustainment of K-12 STEM related programs, the development of professional development opportunities related to STEM and STEM strategies for administrators, and, ultimately, student success in STEM.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Sandy Watson http://orcid.org/0000-0002-8885-6203

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