Technology and Engineering Education Teacher Characteristics: Analysis of a Decade of Institute of Education Sciences Nationally Representative Data

Thomas O. Williams Jr.
Virginia Tech

Jeremy V. Ernst
Embry-Riddle Aeronautical University

Abstract

This study employed four waves of Institute of Education Sciences nationally representative data to investigate changes in K-12 technology and engineering education teachers in terms of demographics, qualifications, and service loads over time through the 2007-2008 and 2011- 2012 *Schools and Staffing Surveys* and the 2015-2016 and 2017-2018 *National Teacher and Principal Surveys*. Gender, age, teaching experience, race, employment status, certification status, certification pathway, teacher placement, educational level, student caseload, categorical student caseload, limited English proficiency caseload, and service load were examined. Most of the characteristics that were examined experienced a modest degree of movement over time.

Keywords: Schools and Staffing Surveys, National Teacher and Principal Surveys, teacher characteristics, technology and engineering education

Introduction and Background

STEM employment opportunities may double in the 2020s, increasing the demand for a refined STEM education system to encompass a greater volume of STEM graduates. Interdisciplinary STEM education approaches to learning position technology and engineering education at the center, where students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise, allowing for the development of broader STEM literacy (Southwest Regional STEM Network 2009, p. 3). Three major and inclusive goals for STEM education were described in two National Research Council (NRC; 2011, 2013) reports on successful K-12 STEM programs in the United States: 1) increase the number of STEM innovators and professionals; 2) strengthen the STEM-related workforce; and 3) improve STEM literacy in all citizens. Technology and engineering education plays a substantial role in enhancing STEM- associated literacy and preparing students for a STEM workforce (ITEEA, 2020). Given the increasing growth, breadth, and interdisciplinary focus, how have teacher credentials, characteristics, and student populations changed technology and engineering education?

Ernst and Williams (2014) stated that utilizing a standardized reporting set could be invaluable in understanding the educational issues affecting teachers. Under the federal educational funding clusters and guidelines, the National Center for Education Statistics (NCES) and the Institute for Education Sciences (IES) employ standardized surveys that encompass the metrics for educators ranging from K-12 where data for these systems are national in scope. Four surveys were used for this study to examine technology and engineering education teacher characteristics: the *2007-2008 Schools and Staffing Survey Teacher Questionnaire* (SASS), the 2011-2012 SASS, the 2015-2016 *National Teacher and Principal Survey* (NTPS) and the 2017-2018 NTPS

Literature Review

There are two models for teaching K-12 students about technology and engineering: 1) a stand-alone course in which the disciplines of technology and engineering are the primary organizers for student learning; examples are Project Lead the Way, Engineering by Design, the Infinity Project, Engineering the Future, or 2) integration of en- gineering and technology concepts and skills into other subjects such as science and mathematics.

The second model has been used for years in individual states and classrooms. Two examples of this approach are Virtual and Physical Modeling--Algebra I and Scientific Visualization--Biology. Both integrated approaches are offered as part of the North Carolina scope and sequence. New Jersey-based educational programs such as the Pre-Engineering Instructional and Outreach Program (Hirsch, Kimmel, Rockland & Bloom, 2005), as well as the recent example of the Qualcomm Thinkabit Inspired-By Schools' programs in California, Louisiana, Michigan, North Carolina, and Virginia (Myers, 2020), situationally apply engineering and technology concepts in the frame of science and mathematics courses.

Apart from subject-specific content knowledge, the ability and confidence to teach across subjects are critical for educators to deliver technology and engineering to K-12 STEM education. Educators will need to understand how to provide instructional supports that assist students in identifying cross-disciplinary linkages, as well as how to support students' increasing competency in specific topics in ways that complement their learning through integrated activities.

Compared to other subject areas, few professional development programs have been created, integrated, and evaluated for K-12 technology and engineering education (e.g., Brophy, Klein, Portsmore, & Rogers, 2008; Hubers, Endedijk, & Van Veen, 2020). In addition, according to the Committee on K-12 Engineering Education (Katehi et al., 2009), teacher preparation programs have produced a modest-sized engineering teaching workforce, and rigorously researched models are scarce.

Some reform efforts have been unsuccessful due to a lack of teachers' attitudes, beliefs, and knowledge (Van Driel et al., 2001). Teacher implementation may influence student results and lead to modifications that are minor or superficial in teaching practice (Archibald et al., 2011; Durlak & DuPre, 2008). One study of K-12 teachers found low levels of familiarity with design, engineering, and technology as well as confidence in their ability to teach engineering (Yasar et al., 2006). Teachers' attitudes of the importance of teaching engineering to students could influence the effort that they exert in learning for themselves, as well as how they instruct their students (Douglas, et al., 2016).

This literature has emphasized the significance of teachers to STEM education and called for educators to cultivate STEM thinking (e.g., National Research Council, 2011; Reeve, 2015). The existing research focuses on professional development that builds STEM skills with practicing teachers (e.g. Havice, Havice, Waugaman, & Walker Donnelly, 2018). Despite the varied results of studies, there is a growing consensus on what constitutes good professional growth. Effective professional development in any discipline should focus on improving teachers' abilities and knowledge to teach content and subject matter, addressing teachers' classroom work, the problems they face in their schools, and providing multiple and sustained opportunities for teacher learning over a long period of time. Professional credentialing activities are not a solution to current limitations on teachers' capacities. Instead, it is more effective to contemplate educator development as a continuum spanning initial preparation, initiation into practice, and then development of a professional network where intentional opportunities are organized to allow for interaction and collaboration with colleagues. A lack of educators in K-12 possessing formal training in engineering creates difficulty in being able to teach engineering material, because introducing engineering in a classroom increases complexity by introducing new content area which must be actively negotiated with other subject areas and includes contemporary approaches to learning (Custer & Daugherty, 2009).

Nadelson and Seifert (2013) and Nadelson, Seifert, Moll, and Coats (2012) have found increased teacher confidence, content knowledge, and use of community resources during an evaluation focusing on knowledge, instruction, and efficacy for STEM. Baxter, Ruzicka, Beghetto, and Livelybrooks (2014) analyzed the outcomes of professional development for teachers to integrate STEM and found increased confidence and perceived changes in practice following the program. Other studies have looked strictly at teachers' implementation of professional development approaches in classroom contexts with a focus on engineering practices.

Roehrig et al. (2012) investigated the application of engineering curriculum and discovered that coteaching and cooperation were beneficial to instructors' STEM practice. Avery and Reeve (2013) found that a supportive learning environment and engineeringfocused professional development had a lasting impact on classroom practice. Guzey, Tank, Wang, Roehrig, and Moore (2014) analyzed a year-long engineering integration program and found effective implementation of engineering practices in classroom contexts.

Capobianco and Rupp (2014) found that, following professional development, teachers implemented engineering practices in the classroom but emphasized problem identification and planning over prototyping. Additional research has focused on STEM teacher learning at the preservice level. Larkin (2013) used six science teacher education programs to describe present STEM teacher education landscape, which help identify differences in priorities and strategic use of resources. Hiebert (2013) presented one approach to STEM teacher preparation that involves clearly defined learning objectives and iterative reflection and improvement of practice. Murphy and Mancini-Samuelson (2012) reported on a STEM concentration for elementary preservice teachers, primarily focusing on content development and inquiry approaches, which found significant increases in preservice teachers' competence and confidence around STEM.

Berlin and White (2012) reported on attitudes toward STEM content integration of preservice teachers enrolled in an integrated STEM preparation program. They found that though there was no change over time in how preservice teachers valued content integration, significant changes in their perception of the feasibility of content integration was present. With the increase of K-12 engineering programs, the National Academy of Engineering Committee on K-12 Engineering Education (Katehi et al., 2009) addressed issues regarding existing engineering PD programs such as pre-service programs with long-term training are more advantageous than the prevalent short-term in-service programs. This is the case because teachers in pre-service programs can spend sufficient time processing multiple engineering concepts, content, and skills through long-term exposure to engineering. Second, if teachers lack confidence in teaching mathematics or science, and they are not familiar with engineering as a subject, they may be unmotivated to teach engineering due to apprehensions manifested as anxiety, fear, low self-confidence, and reluctance.

Research Questions

Ernst and Williams (2014) examined characteristics of technology and engineering education teachers using the 2011-2012 Schools and Staffing Survey and found that there were discrepancies in teacher and student characteristics reported across technology and engineering education literature. Expanding on their study, this research was launched to build a national profile of technology and engineering education teachers that examined teacher and student characteristic trends over time through the employment of four waves of Institute of Education Sciences (IES) data. Specifically, this research addressed the following:

1. How have the characteristics and teaching credentials of technology and engineering education teachers changed over time?

2. What are the student population features and characteristics identifiable within technology and engineering education teachers' classrooms and how have they changed over time?

Data Sources

Data utilized within this study came from the restricted -use 2007-2008 and 2011-2012 *Schools and Staffing Surveys* (SASS) and the 2015-2016, and 2017-2018 *National Teacher and Principal Surveys* (NTPS) developed by the National Center for Education Statistics (NCES) and the Institute of Education Sciences (IES) within the U.S. Department of Education. The objective of the SASS series was to collect information necessary for a comprehensive picture of elementary and secondary education in the United States. The abundance of data collected by the SASS allows for a detailed analysis of the characteristics of schools, principals, teachers, school libraries, and public school district policies.

The NTPS is a redesign of the SASS and many of the questions are identical. The NTPS maintains the same focus on schools, teachers, and administrators that was traditionally held by the SASS. The NTPS collects data on core topics including teacher and principal preparation, classes taught, school characteristics, and demographics of the teacher and principal labor force (Taie & Goldring, 2017; Goldring, Taie, Rizzo & Riddles, 2020).

Methodology

The methodology of this study expanded on Ernst and Williams (2014) ex post facto study of SASS restricted use data in which technology and engineering education teachers were identified by specific content area criteria, and detailed teacher demographics, credentials, and student characteristics were examined. Similarly, in this ex-post facto study, a secondary analysis of the 2007-2008 SASS, 2011-2012 SASS, the 2015-2016 NTPS, and the 2017-2018 NTPS restricted-use data files was employed to examine trends in technology and engineering education teacher demographics, credentials, and student characteristics through descriptive data analyses (frequency-counts, percentages, and mean values). A site license was applied for and approved through IES which granted the researchers permission to access the non-public restricted-use data files. Specific IES reporting protocols were followed and results were submitted to the IES for approval and were authorized for release to the general public. The NCES and IES require that all *n*'s be rounded to the nearest ten to assure participant anonymity. Therefore, data in tables and narrative may not add to the total N reported because of rounding requirements. Any data that did not meet IES reporting requirements were noted in the tables.

All data presented were weighted using variables and procedures recommended by IES. A detailed explanation of data-weighting procedures used by IES can be found in Tourkin, Thomas, Swaim, Cox, Parmer, Jackson, Cole, and Zhang (2010); Cox, Parmer, Strizek, and Thomas (2016); Taie and Goldring (2017) and Goldring, Taie, Rizzo, and Riddles (2020). This resulted in a sample size of 54,570 technology and engineering education teachers within the weighted results for the 2007-2008 SASS; 50,610 within the weighted results for the 2011-2012 SASS; 55,540 within the weighted results for the 2015-2016 NTPS and 43,910 within the weighted results for the 2017-2018 NTPS.

Participant Selection

In this study, teachers who gave subject-matter codes relating to technology and engineering education for the question, "This school year, what is your MAIN teaching assignment field at THIS school?" in the 2007-2008 and 2011-2012 SASS were identified as participants. In the school year, in what subject is your MAIN teaching assignment at THIS school, that is, the subject matter in which you teach the most classes?" was used to identify participants. Table 1 shows the codes and descriptors used to identify these teachers.

Variables Analyzed

Gender, age, teaching experience, employment status, and race/ethnicity were examined to provide a demographic profile. Race and ethnicity were determined by two questions. The first addressed ethnicity by asking, "Are you of Hispanic or Latino origin?" The second asked, "What is your race?" Respondents were instructed to mark one or more of the listed races to indicate what race(s) they consider themselves. Five choices were provided for race: White, Black/African-American, Asian, Native Hawaiian/Other Pacific Islander, or American Indian/Alaska Native. The racial categories listed were taken verbatim from the surveys. Respondents were allowed to make more than one selection and response choices were the same across the four surveys.

The highest degree obtained by the teacher was used as an indicator for education level. This variable considered five levels of degrees ranging from Associates through Doctorate. The surveys recorded the highest degree obtained and did not consider multiple degrees (e.g. Bachelor's and Master's or double Master's).

Certification status was used to identify if teachers were certified in the subject they teach. We chose to report those teachers who responded as being fully certified with no contingencies by the state in which they were employed. Certification route was identified as either alternative or traditional program. An alternative program was described as a program that was designed to expedite the transition of non-teachers to a teaching career, for example, a state, district, or university alternative certification program. Teaching placement was determined by level of students taught as either elementary or secondary

The number of students taught was determined by teachers' responses to how many students they teach per day in their content area. The survey response questions employed to address students with categorical disabilities and students with limited English proficiency (LEP) asked teachers to state how many students in their classes had individualized education programs (IEPs) or were listed with LEP. Service load was calculated by the researchers to be the sum of responses relating to students with categorical disabilities and LEP.

Area	Code	Summary Description
Technology & Engineering Education	246	Construction Technology - (Construction design and engineering, CADD and drafting)
	249	Manufacturing Technology (electronics, metalwork, precision production, etc.)
	250	Communication Technology (Communication systems, electronic media, and related technologies)
	255	General Technology Education (Technological systems, industrial systems, and pre-engineering)

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey (SASS), "Public School Teacher Data File," 2006-2007, 2011–12; National Teacher and Principal Survey (NTPS), "Public School Teacher Data File," 2015–16, 2017-2018.

Table 1. Technology & Engineering teacher placement codes and summary descriptors representing main teaching assignment.

	Male	Female	Mean Age Years	Mean Experience Years	Full-time Status
2007-2008 SASS (n = 54,570)	77.2%	22.8%	45.45	15.07	92.0%
2011- 2012 SASS (n = 50,610)	75.4%	24.6%	46.72	15.48	92.3%
2015-2016 NTPS (n = 55,540)	73.4%	26.6%	47.32	15.00	94.1%
2017-2018 NTPS (n = 43,910)	72.6%	27.4%	45.92	14.13	93.0%

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey (SASS), "Public School Teacher Data File," 2006-2007, 2011–12; National Teacher and Principal Survey (NTPS), "Public School Teacher Data File," 2015–16, 2017-2018.

Table 2. Technology & Engineering educator gender, age, teaching experience, and employment status.

Results

Gender, Age, Teaching Experience, And Employment Status

Demographic information concerning gender, age, teaching experience, and employment status is presented in Table 2. There was an approximate 4.6 percent increase in the number of female teachers from the first wave of data to the fourth wave of data with a corresponding decrease in male teachers. The mean age and the number of years of teaching experience has remained fairly consistent. The full-time employment status has remained in the low 90 percent range, indicating that most teachers were employed full time.

Race and Ethnicity

Self-reported race and ethnicity descriptions are reported in Table 3. Because participants were allowed to make more than one selection, the percentage may not equal 100 percent. The data showed a 2.2 percent decrease in the percentage of White teachers and a 2.4 percent increase in the percentage of Black/African American teachers over time. The percentages for the other groups have fluctuated over time but have remained consistently low as a percentage of technology and engineering education teachers.

	Hispanic	White	Black/ African-American	Asian	Native Hawaiian/ Other Pacific Islander	American Indian/ Alaska Native
2007-2008 SASS (*n* = 54,570)	4.2%	94.0%	4.8%	‡	‡	0.8%
2011- 2012 SASS (*n* = 50,610)	7.0%	91.9%	4.8 %	2.3%	‡	2.7%
2015-2016 NTPS (*n* = 55,540)	5.4 %	91.6%	6.1%	1.0 %	1.2%	1.7%
2017-2018 NTPS (*n* = 43,910)	5.8%	91.8%	7.2%	1.3%	0.4%	2.1%

‡ Did not meet IES reporting requirements.
Note. Percentages may not add to 100 because respondents were allowed to choose multiple categories. Category names were taken directly from the surveys.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey (SASS), "Public School Teacher Data File," 2006-2007, 2011–12; National Teacher and Principal Survey (NTPS), "Public School Teacher Data File," 2015–16, 2017-2018.

Table 3. Technology & Engineering educator self-reported race and ethnicity.

	Associate's	Bachelor's	Master's	Educational Specialist	Doctorate
2007-2008 SASS (*n* = 54,570)	14.3%	43.4%	36.3%	4.5%	1.5%
2011- 2012 SASS (*n* = 50,610)	16.7%	37.4%	40.4%	4.6%	0.9%
2015-2016 NTPS (*n* = 55,540)	17.4%	38.3%	36.6%	7.1%	0.5 %
2017-2018 NTPS (*n* = 43,910)	12.9%	37.5%	40.9%	7.2%	1.5%

Note. Percentages may not add to 100 because of rounding requirements.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey (SASS), "Public School Teacher Data File," 2006-2007, 2011–12; National Teacher and Principal Survey (NTPS), "Public School Teacher Data File," 2015–16, 2017-2018.

Table 4. Technology & Engineering educator highest degree obtained.

Level of Education

Table 4 shows the highest reported level of education. It should be noted that only the highest degree obtained is reported. With regard to highest degree obtained, there has been a steady increase in the percentage of teachers indicating a Master's and Educational Specialist degree and a decrease in the percentage of those indicating a Bachelor's degree.

Teaching Credentials: Certification Status, Certification Route, and Placement

Table 5 shows the certification status, certification route, and school placement. There has been a slight percentage decrease in the number of fully certified teachers and alarge percentage increase (14.2 percent) for those who chose alternative routes to certification. The majority of technology and engineering education teachers teach at the secondary level.

Caseloads

The caseloads of technology and engineering education teachers are illustrated in Table 6 pertaining to the total number of students served, students with individualized education programs (IEPs), students who are identified as limited English proficienct, and the total service load, which is the sum of students with IEPs and those who with limited English proficiency. Over time, the caseload of students has slightly increased. The number of students with categorical disabilities has increased as well as the number of students with limited English proficiency. The service load has also increased over time.

Findings and Conclusions

Evidenced through findings of this study, the number of technology and engineering education teachers has averaged in the low to mid-50,000 across three waves of national data representing 2007-08, 2011-2012, and 2015-16. However, the 2017-2018 data show a marked decrease of almost 12,000 technology and engineering education teachers. This decrease is inconsistent with previous waves of national data. At the time of this study, data are being collected for the 2020-2021 cycle. It would be interesting to see if this downward data trend holds for the next wave of data.

The percentage of male teachers is slowly decreasing with a proportionate increase in female teachers. With regard to the ethnicity and racial make-up, it has remained over 90 percent White. However, this percentage is slowly decliningover time while the percentage of Hispanics or Black/African Americans are going up. The percentage of those reporting as Asian, Native Hawaiian/ Other Pacific Islander, and American Indian/Alaskan Native were very low and in some cases the data were not stable. Therefore, it was difficult to establish a trend for these groups.

With regard to highest degrees earned, Master's degrees have increased over time, while the percentage indicating Bachelor's degrees and Doctorate degrees has decreased. The percentage with full state certification has decreased slightly over time, while the percentage receiving certification from alternative programs has increased. Technology and engineering education teachers primarily work in secondary settings.

The categorical and LEP caseloads have increased over time. Specifically relating to students with categorical disabilities and LEP, this may prove to be problematic.

	State certified	Alternative program	Traditional program	Elementary	Secondary
2007-2008 SASS (n = 54,570)	84.4%	24.2%	75.8%	5.2%	94.8%
2011- 2012 SASS (n = 50,610)	85.8 %	21.6%	78.4%	9.3%	90.7%
2015-2016 NTPS (n = 55,540)	82.1%	38.2%	61.8%	6.6%	93.4%
2017-2017 NTPS (n = 43,910)	82.5%	38.9%	61.1%	8.2%	91.8

Note. Percentages may not add to 100 because of rounding requirements.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey (SASS), "Public School Teacher Data File," 2006-2007, 2011–12; National Teacher and Principal Survey (NTPS), "Public School Teacher Data File," 2015–16, 2017-2018.

Table 5. Technology & Engineering educator state certification, career path entry, and location.

	Overall Caseload	Categorical	LEP	Service Load
2007-2008 SASS (n = 54,570)	93.30	14.33	5.08	19.41
2011- 2012 SASS (n = 50,610)	91.76	18.87	7.60	26.47
2015-2016 NTPS (n = 55,540)	96.37	16.94	6.81	23.75
2017-2018 NTPS (n = 43,910)	92.03	19.01	9.97	28.98

Note. Categorical are students individualized education programs. LEP is limited English proficiency. Service Load is the sum of Categorical and LEP.
SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey (SASS), "Public School Teacher Data File," 2006-2007, 2011–12; National Teacher and Principal Survey (NTPS), "Public School Teacher Data File," 2015–16, 2017-2018.

Table 6. Technology & Engineering educator mean caseloads.

However, the standard deviation in the caseload numbers for these students indicated that there can be consider -able variability across teachers. Regardless, the trend for the number of students with disabilities and limited English proficiency are increasing, and additional training may be necessary to meet the academic and behavior demands of these students in the classroom. Technology and engineering education teachers must be prepared to offer all learners interdisciplinary experiences that bridge academic and real-world applications connecting school with life, society, work, and the world.

Implications for Future Research

Technology and Engineering education teachers are tasked with increasingly complex educational demands and accountability but are often not provided with the necessary training and support to undertake these demands. Their caseloads are growing for students with disabilities and for students with limited English proficiency. If this trend holds for the future, technology and engineering education teachers will find themselves tasked with more students in general and with more students with disabilities and limited English proficiency. How will this impact the technology and engineering education classroom? How will this affect technology and engineering education teacher preparation programs? How will this affect teacher retention and job satisfaction?

In regard to increasing the diversity of technology and engineering education teachers, there has been some progress made. There has been a slight increase in minority teachers over time and a slight increase in female teachers. Although the results are promising for increasing diversity, they are underwhelming. It also appears that technology and engineering education teachers are increasingly entering into the field through alternative programs. What impact will this have on programs at colleges that offer licensure? Will licensure programs and program numbers decrease over time as well?

The use of nationally representative data sets is an important step in examining characteristics of technology and engineering education teachers that may have an impact on the field. These data sets are meant to represent the population of teachers at a given point in time. This research addresses issues pertinent to technology and engineering education teachers and are presented to generate discussion across the field concerning these issues. These findings are suggestive that technology and engineering education classrooms are becoming increasingly crucial to inclusivity in STEM education for secondary learners. The researchers of this study urge educational providers to revisit educational preparation models to account for the increased service loads of students with disabilities and limited English proficiency. This can guide teacher preparation, state credentialing, and suitability of career path entry considerations for increased effectiveness of technology and engineering education teacher readiness and practice.

The Virginia Tech Open Access Subvention Fund supplied funding for this article.

References

Baxter, J. A., Ruzicka, A., Beghetto, R. A., & Livelybrooks, D. (2014). Professional development strategically connecting mathematics and science: The impact on teachers' confidence and practice. *School Science and Mathematics, 114*(3), 102 113.

Berlin, D. F., & White, A. L. (2012). A longitudinal look at attitudes and perceptions related to the integration of mathematics, science, and technology education. *School Science and Mathematics, 112*(1), 20–30.

Berlin, D. F., & White, A. L. (2012). A longitudinal look at attitudes and perceptions related to the integration of mathematics, science, and technology education. *School Science and Mathematics, 112*(1), 20–30.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education, 97*(3), 369-387.

Cox, S., Parmer, R., Strizek, G., & Thomas, T. (2016). *Documentation for the 2011–12 Schools and Staffing Survey* (NCES 2016-817). U.S. Department of Education. Washington, DC: National Center for Education Statistics. Retrieved June 17, 2014 from http://nces.ed.gov/pubsearch.

Custer, R. L., & Daugherty, J. L. (2009). Professional development for teachers of engineering: Research and related activities. *The Bridge: Linking Engineeringand Society, 39*(3), 18-24.

Douglas, K. A., Rynearson, A., Yoon, S. Y., & Diefes-Dux, H. (2016). Two elementary schools' developing potential for sustainability of engineering education. *International Journal of Technology and Design Education, 26*(3), 309-334.

Ernst, J.V. & Williams, T.O. (2014). Technology and engineering education accommodation service profile. *Journal of Technology Education, 26*(1), 64-74.

Goldring, R., Taie, S., Rizzo, L., and Riddles, M. (2020). User's Manual for the 2017–18 *National Teacher and Principal Survey Volume 4: Public and Private School TeacherDataFiles* (NCES 2020–214). U.S. Department of Education. Washington, DC: National Center for Education Statistics.

Guzey, S. S., Tank, K., Wang, H.., Roehrig, G., & Moore, T. (2014). A high-quality professional development for teachers of grades 3-6 for implementing engineering into classrooms *School Science and Mathematics, 114*(3), 139–153.

Havice, W., Havice, P., Waugaman, C. & Walker Donnelly, K. (2018). Evaluating the effectiveness of integrative STEM education: Teacher and administrator professional development. *Journal of Technology Education. 29*(2) 73-90.

Hirsch, L. S., Kimmel, H., Rockland, R. & Bloom, J. (2005). Implementing pre-engineering curricula in high school science and mathematics, Proceedings Frontiers in Education 35th Annual Conference, Indianapolis, IN, 2005, p. S2F-21.

Hubers, M.D., Endedijk, M. & Van Veen, K. (2020). Effective characteristics of professional development programs for science and technology education, *Professional Development in Education*, doi:10.1080/19415257.2020.1752289

International Technology & Engineering Educator Association (2020). Standards for technological and engineering literacy: The role of technology and engineering in STEM education. STEL.aspx

Larkin, D. (2013). Structures and strategies for science teacher education in the twenty-first century. *Teacher Education and Practice, 27*(2-3), 224–247

Murphy, T.P., & Mancini-Samuelson, G.J. (2012). Graduating STEM competent and confident teachers: The creation of a STEM certificate for elementary education majors. *Journal of College Science Teaching, 42*(2), 18.

Myers, V. (2020). Inspiring the next generation of inventors. Qualcomm Thinkabit Lab News. San Diego, CA Retrieved from https: thinkabitlab.com/

Nadelson, L. S., Seifert, A., Moll, A. J., & Coats, B. (2012). I-STEM summer institute: An integrated approach to teacher professional development in STEM. *Journal of STEM Education, 13*(2), 69–83

National Research Council (2011). *Successful K-12 STEM education: identifying effective approaches in science, technology, engineering, and mathematics.* Washington, DC: The National Academies Press.

National Research Council (2013). *Monitoring progress toward successful K-12 STEM education: a nation advancing?* Washington, DC: The National Academies Press.

Southwest Regional STEM Network (2009). *Southwest Pennsylvania STEM network long range plan (2009–2018): plan summary*, (p. 15). Pittsburgh: Author.

Taie, S., & Goldring, R. (2017 *Characteristics of Public Elementary and Secondary Schools in the United States: Results From the 2015–16 National Teacher and Principal Survey First Look* (NCES 2017-071). U.S. of Education. Washington, DC: National Center for Education Statistics. https://nces.ed.gov/pubs2017/2017071.pdf .

Tourkin, S., Thomas, T., Swaim, N., Cox, S., Parmer, R., Jackson, B., Cole, C., & Zhang, B. (2010). Documentation for the 2007–08 Schools and Staffing Survey (NCES 2010-332). U.S. Department of Education. Washington, DC: National Center for Education Statistics. Retrieved June 17, 2014 from http://nces.ed.gov/pubsearch

Thomas O. Williams Jr. is a Professor in the Special Education program in the School of Education at Virginia Tech. His educational background is in psychology, special education, and rehabilitation. He specializes in research in special education, teacher retention, disability related issues in STEM education, and psychoeducational assessment. He can be contacted via email at: thwilli1@vt.edu

Jeremy V. Ernst is Professor and Vice President for Research and Doctoral Programs at Embry-Riddle Aeronautical University. Jeremy has doctoral and master's degrees in Engineering and Technology Education from North Carolina State University in Raleigh as well as a bachelors in Technology and Human Resource Development from Clemson University. Jeremy's research focuses on students identified as at-risk of dropout or nonmatriculation in STEM majors. His efforts center on curriculum research and development in STEM education to provide evidencebased models that promote engagement, development of cognitive competency sets, and performance-based application abilities of students at-risk.