International Journal of Engineering Education Vol. 37, No. 4, pp. 925–938, 2021
Printed in Great Britain
0949-149X/91 $3.00+0.00

Impact of a High Value Manufacturing Research and Enrichment Experience on Self-Efficacy of High School STEM Teachers*

VASU KUMAR
Department of Industrial and Systems Engineering, Texas A&M University, College Station, TX, USA.
E-mail: vasukumar@tamu.edu

MICHAEL D. JOHNSON
Department of Engineering Technology and Industrial Distribution, Texas A&M University, College Station, TX, USA.
E-mail: mdjohnson@tamu.edu

BIMAL NEPAL
Department of Engineering Technology and Industrial Distribution, Texas A&M University, College Station, TX, USA.
E-mail: nepal@tamu.edu

GOURAV GHOSHAL
Department of Industrial and Systems Engineering, Texas A&M University, College Station, TX, USA.
E-mail: ghoshal.gourav@gmail.com

The manufacturing industry is one of the largest employers in the US and plays a vital role in contributing to the US economic growth. The prospects of manufacturing growth and stability are the focus of many developed nations. However, the recent fast paced advancements in manufacturing technologies have created a void in the talent pool that requires a skilled workforce to fill in the gap. Prior research shows that the foundation of STEM education, including advanced manufacturing, is laid out during K-12 education. Further, high school teachers with higher self-efficacy beliefs are found to be more successful in generating interest and highlighting value of STEM education in their students. The prior research also reveals that, in addition to their self-efficacy beliefs, teachers' perception of manufacturing can also impact interest among their students. To that end, this research aims to investigate the impact of an intervention program (an engineering research and enrichment experience) on the self-efficacy of the secondary teachers. Specifically, this study focuses on impact of an enrichment experience in engineering (E3) program designed for high school teachers to boost their engineering/manufacturing self-efficacy. The paper investigates the teachers' understanding of manufacturing and how their perception about manufacturing changed after partaking in the E3 program. It uses the T-STEM instrument to evaluate the self-efficacy beliefs of E3 participants and to determine the effectiveness of the program. The paper also presents a comparative analysis of teachers' self-efficacy between various population groups divided by gender, ethnicity, and school type. The survey results show that the E3 program improved the self-efficacy of the teachers across all the population groups although with some variations among the groups in the net gain in post program efficacy.

Keywords: High-Value Manufacturing (HVM); teacher self-efficacy; STEM education; K-12

1. Introduction

The manufacturing industry employs a significant portion of the working population in the US and plays an important role in US economic growth. In 2018, industrial and manufacturing sectors represented $2,335 billion in economic activity, accounting for over 11% of the total economic output in the US. These sectors of the US economy employed around 12.8 million people in 2018 [1].

Since 2012, the US government has invested in national networks for manufacturing innovation (also known as Manufacturing USA) that provide a collaborative manufacturing research infrastructure to the US and through regional manufacturing innovation institutes that provide workforce training in manufacturing [2]. Investments in manufacturing have a strong multiplier effect; every dollar spent in manufacturing adds $1.37 to the US economy and every job in a manufacturing creates an additional 2.5 jobs in other sectors [3]. In manufacturing alone, the National Association of Manufacturing (NAM) and Deloitte predict that as many as 2 million manufacturing jobs in the US will go unfilled, due to the inability to find people with the necessary skills [4]. A recent US Congressional study [5] noted that manufacturers preferred workers with "academic-track associate degrees". The future workforce in engineering will require critical thinking, creativity, communication and problem solving skill sets at a much higher level when compared to the previous generations. Manufacturers

* Accepted 3 February 2020.

are concerned about the "largest gap" with respect to technical knowledge, business skills, problem solving abilities [7].

There has been a constant debate over the past decade about the prospects of industrial and manufacturing sectors in the US and other developed nations. The usual image portrayed by the Americans regarding manufacturing jobs are about large components, small dirty floors incorporating menial and dead-end jobs [8]. Modern manufacturing has changed dramatically and does not resemble the "dirty factory floors" of the past. There is a requirement for higher degrees of technological capabilities, leveraging modern technologies, and implementing processes often entirely computer based in the advanced manufacturing sectors. In addition to technologies associated with Industry 4.0: additive manufacturing, big data, automation, and IoT, there are also significant electromechanical systems (mechatronics) in modern manufacturing. In Holden [9], a report submitted to the President of the United States on ensuring US leadership in advanced manufacturing, several proposals for necessary improvements in manufacturing were laid out.

In spite of a national emphasis on Science, Technology, Engineering, and Math (STEM) fields as shown in the Bureau of Labor Statistics data presented in Fig. 1, there is a clear deficit in the number of hires in comparison to the total number of job openings in the STEM fields. The gap between job openings and the number of hires has increased in recent times and that trend is expected to continue in future due to significant gaps in STEM skills [10]. A survey by an educational instrumentation manufacturing company Emerson [11] found students today are twice as likely to study STEM fields compared to their parents, but the survey also suggests that the "number of roles requiring STEM expertise is growing at a rate that exceeds current workforce pipeline". According to U.S bureau of labor statistics, the knowledge and abilities of STEM have grown in demand beyond STEM-specific jobs into all types of occupations [12, 13]. Similarly, the US National Science Foundation (NSF) which supports advanced technological education programs (primarily in two-year colleges) asserts that students must possess knowledge and skills relevant to STEM in order to succeed and prosper in the 21st century global economy [14]. Prior studies indicate that the elementary years of education are the best place to lay the foundational knowledge of STEM; therefore, students must be given sufficient exposure to STEM subjects starting right from kindergarten through 12th grade [15]. Furthermore, prior research also suggests that the knowledge, skills, and beliefs of the schoolteachers play an extremely important role [16] in student success in K-12 STEM education. STEM courses in high schools are also positively related to increased STEM achievements [17], odds of choosing STEM Major [18], and a reduction in odds of dropping out from high school [19]. Recent studies show that there exists a significant gap in the knowledge, skills, and efficacy beliefs among the instructors, which makes it difficult for them to deliver STEM education to their students [20, 21]. To that end, this paper presents results from an enrichment experiences in engineering program that is designed to improve the self-efficacy of secondary teachers.

The objective of this research is to investigate the current STEM self-efficacy level of secondary teachers and evaluate the impact of the proposed approach on the improvement of their self-efficacy. In particular, this paper evaluates the impact of the enrichment experience intervention in engineering on secondary teachers on their STEM self-efficacy. The enrichment program included a research and curriculum development internship with manufacturing faculty at the university. The study also examines the impact of the enrichment program

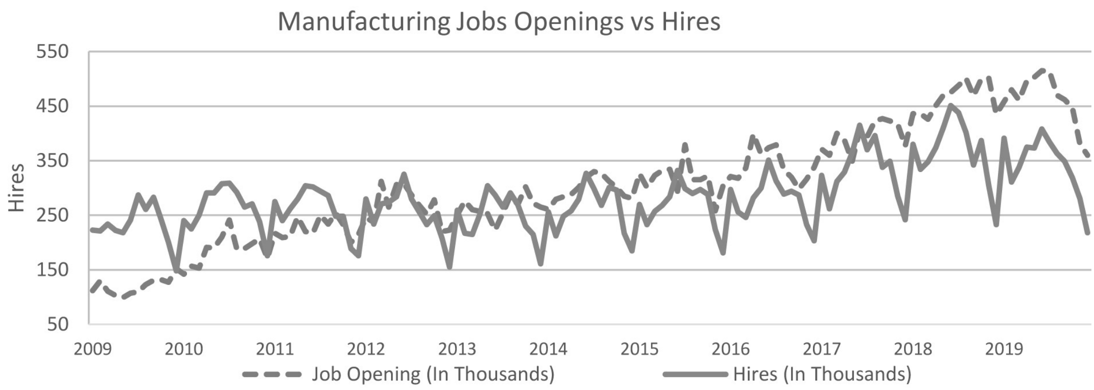

Fig. 1. Gap between Job Openings and Number of Hires (Data Source: Bureau of Labor Statistics) [10].

on teacher's self-efficacy by gender, ethnicity, and type of school to understand if there are any underlying differences among different population groups. Lastly, results of a follow-up survey after the summer program and how the teachers were able (or unable) to incorporate the lessons are discussed along with implications for future programs.

The paper is structured as follows. Section 2 provides an overview of related prior research on teacher self-efficacy, its relationship with STEM education, and the instruments that have been used to measure that self-efficacy. In section 3, we describe in detail the research design and instruments used in the study. Section 4 presents analysis and results of this study. Finally, section 5 summarizes the paper by highlighting key findings. This section also provides a discussion on the limitations of this study along with the few directions for future work.

2. Literature Review

This section provides an overview of self-efficacy literature with a focus on efficacy in STEM education. The literature review is organized into four key aspects of STEM self-efficacy, but especially for manufacturing with respect to secondary school teachers. Those aspects include self-efficacy of teachers, correlation between teacher's self-efficacy and student success, self-efficacy assessment methods, and methods to improve self-efficacy.

2.1 Background on Self-Efficacy and Self-Efficacy of Teachers

Self-efficacy was first defined in the seminal work of Bandura [22], as "beliefs in one's capabilities to organize and execute the courses of actions required to produce given attainments". Tschannen-Moran and Hoy [23] describe self-efficacy as a belief that reflects the degree of confidence. It enables one to take action to achieve a target. Individuals with a lower sense of self-efficacy perceive themselves as incompetent, do not participate in challenging tasks, and give up in difficult situations [24].

In the context of schools, teacher self-efficacy refers to teacher's efficacious beliefs in his/her abilities to perform at a specified level of quality in a specified situation [25] to promote student learning and success. Nadelson et al. [16] report that teacher self-efficacy has proven itself to be a key factor in student learning and extremely important for successful teaching. Teacher self-efficacy plays a key role in the amount of effort they put forth and display of perseverance when faced with difficult scenarios [26–28]. Teachers with a strong sense of teaching efficacy were found to excel in areas of planning and organization and were more open-minded towards using radical techniques to cater to student needs [29, 30]. Additionally, they tended to implement innovative curriculum, promote student autonomy, have better classroom management, promote a more positive environment, keep students focused, and have better relationships with parents and colleagues [31–35]. The efficacy beliefs of a teacher can significantly alter their perceptions and judgment abilities which in turn can affect student learning [36]. One of the studies shows that the choice of engineering as a major is influenced by the role of science activities at school, teachers and parents [37]. The construct of teaching self-efficacy has been divided into two major sections: personal teaching efficacy that relates to the teacher's level of confidence with regards to his/her teaching abilities; and general teaching efficacy that refers to a generalized belief on the ability to teach difficult children [38]. These two sections together influence the teacher's beliefs in his/her ability to positively affect students' learning outcomes.

2.2 Relationship Between Self-Efficacy of Teachers and Students' Outcomes

Researchers have investigated the association between teacher self-efficacy and student achievements for the past 20 years [39, 40]; they find that a teacher's sense of both self and collective efficacy is positively related to student's academic achievement. A higher level of efficacy results in positive outcomes from the student's academic performance [39, 41]. For example, Olsen [39] reports that teachers with a higher sense of efficacy devote more classroom time to helping struggling students, and tend to praise the academic achievements of their students more as compared to their peers with lower self-efficacy. Teachers with strong self-efficacy beliefs have the potential to increase their persistence and resilience, particularly when things do not turn out as expected [23]. In other words, the self-efficacy literature suggests that stronger self-efficacy beliefs result in better student performance [42–44]. The key is to promote an epistemological view of technical knowledge as changing [45, 46].

2.3 Instrument to Measure Self-efficacy

The importance of teaching self-efficacy in the domain of education has led to the development of multiple instruments to measure self-efficacy over the years. Several self-efficacy instruments have been developed. These include the Teacher Efficacy Scale (TES) by Gibson and Dembo [34] and Ashton vignettes by Ashton and Webb [47]. The TES instrument has a 30-item scale yielding two factors – the Personal Teaching Efficacy (PTE) and General Teaching Efficacy (GTE). The PTE is used for assessing self-efficacy and the GTE is used for assessing outcome expectancy. These are consistent with the Rand Corporation framework on teaching efficacy [48] – which was interpreted through Bandura's Social Learning Theory. However, multiple studies on this scale [49–51] that were conducted later and reported inconsistencies and theoretical problems; this led to uncertainty regarding the resultant findings. The Ohio State University (OSU) Teaching Scale, developed by Hoy et al. [28] was based on numerous teaching skills. It considered a teacher's capabilities in different domains such as managing the classroom, evaluating students' performance, and using radical learning methods focusing on creating a sense of cooperativeness amongst the students. There are 32 items in this scale. In 2008, Dellinger et al. [25] developed multiple scales, among which a practical-oriented application is the *teachers' efficacy beliefs system* (TEBS)-self scale instrument. More recently, the Friday Institute at North Carolina State University developed a T-STEM (Teacher-STEM) scale for measuring and determining a teacher's level of confidence and self-belief in teaching STEM subjects, outcome expectancies and STEM-specific career awareness [52].

2.4 Common Approach to Improve Self-Efficacy of STEM Teachers

The early versions of teacher self-efficacy scales did not separate the teachers by subject area. However, as reported in Brand and Wilkins [53] having self-efficacy on STEM was found to be critical for STEM teachers. Nadelson [16] found that a strong correlation between a teacher's level of confidence and efficacy with their mathematics and science knowledge. Specific tools to measure self-efficacy have been developed for mathematics [54] and engineering [55]. More recently, Avery and Reeve [56] reported that integrating STEM education at K-12 levels was the way for the US to remain competitive globally. However, there are very few works in the literature that report the impact of teacher's self-efficacy beliefs in the context of STEM integrated K-12 education, although research has been done in exploring the details of science [57], mathematics [54], and technology [58]. The majority of prior studies are focused on the post-secondary education and there is very limited literature on the studies related to impact of teacher's self-efficacy at the K-12 level in STEM fields, especially in manufacturing. This paper attempts to narrow that gap by studying the impact of an enrichment program on improvement in teacher's STEM and manufacturing self-efficacy which in turn is expected to have a positive effect in their student's learning.

3. Research Design

Since knowledge and beliefs of schoolteachers are the key drivers of student's academic success at the school level, this research aims to investigate secondary teachers' competencies in advanced manufacturing. It may be noted that the prior studies conducted by Wang et al. [20] and Xie et al. [21] found a significant gap in the knowledge, skills, and beliefs among instructors; this limits their ability to provide STEM education. This paper evaluates an enrichment program in engineering and manufacturing as an intervention method to investigate its impact on secondary teacher's self-efficacy. In addition to assessing teachers' self-efficacy upon completion of the enrichment program, the proposed research also studies the curriculum development activities and student performance to investigate the broader impact of the enrichment program. The following sections describe overall research design including an overview of the enrichment program, related activities, survey instrument, and the qualitative methods used in the research.

3.1 E3 Enrichment Program

The E3 program was offered as a part of National Science Foundation's Advanced Technological Program grant. The program included a three-week summer residential research experience for high school teachers at Texas A&M's College Station campus. The objective of this program was to provide the high school teachers with insight into engineering research (particularly focused on high value manufacturing) so they could develop engineering/manufacturing related projects for their own classroom implementation to increase the student's awareness of the career opportunities present in manufacturing. The participants were secondary level mathematics, science, and career and technical education (CTE) teachers from different school districts in Texas. This was done in collaboration with the College of Engineering's E3 program [56]. The mission of the program is to "excite, empower, and educate teachers about engineering so that they, in turn, will excite, empower, and educate students and any other teachers they come in contact with each day" [59] .There were two cohorts of teachers (eleven in total) that were provided with the residential research experience program in the summers of 2017 and 2018. Their experience included both research and lab work along with enrichment seminars from expert faculty and the instructors from Texas A&M University's Center for Teaching Excellence. In addition, the participants were also engaged in curriculum planning and development activities organized by the College of Engineering which coordinated the summer research program for all teachers including the ones that were part of this study. Each teacher was paired with a faculty mentor and/or a graduate student to provide the teachers with proper guidance and mentoring to maximize the learning. In addition to faculty and graduate student mentors, a master teacher was recruited from a prior cohort who had been through similar program and was successful in translating his/her summer research experience into classroom instructions at his/her school. Likewise, in addition to a specific research project, the other enrichment activities included lab tours across the College of Engineering, safety training, curriculum design and planning workshops, and research and teaching seminars as mentioned earlier.

3.2 Curriculum Design for K-12 Students

As mentioned above, the participants in the summer enrichment program were assigned the task of using the materials learned in the program to develop a curriculum that could be taught to students at their school. The objective of the assignment was to incorporate the learning into the classrooms of high school students. Below are the brief descriptions of illustrative projects the participants were involved in and how they integrated their learning into K-12 classroom activities.

1. Electro and Electroless Nickel plating were studied in the program to achieve corrosion resistance layers using the nano-technology process. Depositing of thin-film layers is a facet of nanotechnology that holds provocative applications in several disciplines of science that could benefit mankind. The learning in the project helped in creating a framework for high school students to demonstrate the nanotechnology processes with emphasis on 3D printing pendants, by determining the weight of the student-created 3D pendant before and after the electrochemical process. To achieve the best successful process, students need to create a design of an experiment to determine which temperature and pH value will give the maximum plating coverage.
2. Fracturing behavior of Advanced High Strength Steel (AHSS) was studied under external loads in tensile testing. Using the learning from this project a curriculum for Principles of Engineering and Engineering Design & Development courses was developed where high school students would study the stress-strain diagram to identify the best conditions to form a material as well as a necking region where a specimen's fracture stress point would soon occur.
3. How to incorporate Cellulose Nanocrystals with Carbon Nanotubes by Vacuum Assisted Resin Transfer Molding was studied in the project to understand the impact it makes on the high-value manufacturing domain. The quantitative nature and the data analytics involvement of the project inspired the participant to create a lesson centered around the measurement, design, and construction for the high school students.
4. Shape memory polymers (SMPs) were studied in the project and their ability to change shape under external stimuli, such as heat inspired the participant to come up with the curriculum project to design and develop scaled models for disaster relief structures that can be folded into a small area for shipping and expanded into a rigid structure to shelter a family of four.
5. Various domains of manufacturing engineering were studied such as supply chain management, quality assurance, and industrial distribution. Learnings from lean principles in distribution helped the participant in developing curriculum for high school students which was expected to enhance the understanding of the field and improve awareness of the various career options in this domain.
6. Rapid prototyping (RP) using additive manufacturing technologies was evaluated in another project. In additive manufacturing, layer by layer printing of 3D CAD models using extruded plastic filament and the materials with better mechanical properties were studied, which helped in developing the curriculum for an Engineering Design and Presentation course using various fused filament fabrication (extrusion) technologies and variable mechanical properties of thermoplastic filament materials.

3.3 Survey Design

This research uses mixed method approach and includes both quantitative and qualitative information. Therefore, the survey instrument included both quantitative response (1–5 Likert scale) and qualitative response (through open ended questions). The participant teachers, eleven in total, were first surveyed on their beliefs relevant to manufacturing technology. The participants were surveyed before the E3 program to gauge the perception of the participants about manufacturing and after the program to evaluate the effectiveness of the program. In addition to measuring the effectiveness of the program in improving their awareness about manufacturing, the post survey instrument also included questions on the operations and logistics aspects of the E3 program itself.

The T-STEM instrument [52] was used both before and after the program to determine how each of the participants judged themselves on areas associated with teaching self-efficacy – technology teaching efficacy and beliefs, technology teaching outcome expectancy, student technology use, technology instruction, 21st-century learning attitudes and STEM career awareness, in all consisting of 63 questions. The purpose of using the same T-STEM before and after the E3 program was to examine the effect of the program on improving the self-efficacy of teachers on the various aspects of T-STEM survey.

3.4 T-STEM Instrument Description

The T-STEM instrument was developed in 2012 and 2015 by the Friday Institute for Educational Innovation at North Carolina State University [52]. The instrument is a survey questionnaire consisting of 63 total questions divided into 7 constructs as described in Table 1. Each of the seven constructs of the survey was adapted from other well-known surveys, thereby making this T-STEM instrument robust and comprehensive [52, 60]. The response to each question was recorded on a five-point Likert [61] scale consisting of the following choices- Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree and Strongly Agree. As mentioned earlier, apart from filling out the T-STEM survey, the teachers were also asked to fill out two separate sets of questions- one pre-enrichment survey, asking the teachers about their beliefs regarding manufacturing technology and another post-enrichment survey, asking them about their experiences in the E3 program. Furthermore, the teachers were also asked for demographic information. The purpose of demographic information is to analyze if there was any significant difference in self-efficacy level among different demographic attributes such as gender, ethnicity, or education level.

3.5 Research Questions and Hypothesis

The objective of the E3 program was to introduce high school teachers to advanced manufacturing research so that this knowledge increased their confidence and helped them in providing more effective instruction. To that end, the objective of program assessment is to investigate if there was significant impact of the program on the change in self-efficacy of teachers. This section discusses the proposed research questions and hypothesis considered in this study.

The first research question formulated in this study is about whether or not teachers' perceptions, self-efficacy beliefs, and outcome expectancies change significantly after partaking in the E3 program. Thus, the first set of hypotheses developed in this study aim to examine if there were any significant differences in the pre and post scores related to teachers' perceptions, self-efficacy beliefs, and learning outcome due to E3 program.

Interactive technological resources can play a significant role in teaching and learning [62]. The learning process in today's environment is highly impacted by technology; the attitude towards the use of technology among instructors depends on the kind of exposure they receive in their life. Since the amount of technological exposure could depend on the resources available at a school district (e.g., rural school district versus suburban school district), this study divided the participants by the location of their respective schools to gauge their self-efficacies in different sections. Afterward, the difference between post and pre-test scores for each of the groups were calculated to highlight any statistically significant variations. The second research question asked whether teacher's self-efficacy beliefs and outcome expectancies depend on the type of school district they teach in. The null hypotheses for the second research question state that there are no statistically significant differences in teacher's self-efficacy beliefs and outcome expectancies based on their school district type.

While women have made significant strides in other professions (e.g., law, medicine), that has not been the case in science and engineering [63]. While prior research shows that a program like E3 have been successful in improving the self-efficacy beliefs among participants in general [64, 65], in this study, gender and ethnicity dimension with respect to the

Table 1. T-STEM instrument sections [52]

Section	Construct	Section description
A	Technology Teaching Efficacy and Beliefs	Belief in technology teaching ability
B	Technology Teaching Outcome Expectancy	Belief in the extent to which effective teaching affects student learning in technology domain
C	Student Technology Use	Frequency of student technology use during instruction
D	Technology Instruction	Frequency of using technology instructional practices
E	21st Century Learning Attitudes	Attitude towards 21st century learning
F	Teacher Leadership Attitudes	Attitude towards teacher leadership activities
G	STEM Career Awareness	Awareness of STEM career prospects

Table 2. Research questions and population groups

Research Question	Teacher Group	Mean Scores Compared	Instruments Analyzed
RQ1: *Effect of E3 Program on Perception, Self-efficacy beliefs and outcomes*	All Teachers	Pre- and post-survey	7 T-STEM instruments
RQ2: *Effect of type of school districts on Teacher's self-efficacy beliefs and outcome expectancies*	City and Non-City (Sub-urban/Rural)	Pre-survey	
		Post-survey	
		Pre- and post-survey	
RQ3: *Effect of Gender on manufacturing self-efficacy and beliefs of teachers*	Female vs Male	Pre-survey	
		Post-survey	
		Pre- and post-survey	
RQ4: *Effect of Ethnicity on manufacturing self-efficacy and beliefs of teachers*	URM vs Non-URM	Pre-survey	
		Post-survey	
		Pre- and post-survey	

impact of E3 program on teachers' STEM self-efficacy were also evaluated. To that end, the third research question investigates the effect of gender and underrepresented status on improvement of teacher's self-efficacy beliefs. Table 2 presents the summary of research questions and corresponding populations considered for inferential statistical analysis.

4. Data Collection and Analysis

The data for this study was collected at three different times, the first two (pre- and post-E3) surveys were conducted while the teachers were on Texas A&M University campus for the enrichment program. In other words, the "pre" survey was done on the very first day following the kick-off meeting and the "post" survey was conducted after they completed the final presentation to the faculty and other members of the college of engineering. Lastly, the third survey was conducted after they had implemented their curriculum from the program. In other words, the follow up survey for 2017 cohort was conducted in summer 2018. Likewise, the follow up survey for 2018 cohort was conducted in early 2020.

The data set included 11 high school teachers (5 from 2017 cohort and 6 from 2018 cohort). In both years, the teachers participated in manufacturing related projects as shown in Table 3. All 11 participants completed the pre and past survey while only 10 teachers completed the follow-up survey as the eleventh teacher reported that she could not implement anything because of lack of resources. An IRB approved protocol was used in gathering the data.

4.1 Participants Summary

Fig. 2 provides summary statistics of participants based on gender and ethnicity. In addition, it also provides a comparative insight on the participant's diversity in the context of national average in the STEM fields. As shown in Fig. 2(b), the E3 program had 81.82% of participants (nine out of eleven) from underrepresented groups (URG) in the STEM workforce, which is higher than the 2013 national average of 35%. Further, seven out of eleven participants were female.

4.2 Data Analysis

The T-STEM survey responses were collected using a 5-point Likert [61] scale where 1 meant "strongly

Table 3. Manufacturing related projects carried out by the Teachers

Cohort	Projects in the HVM Areas	Description
2017	3D Printing	3 D modeling, and rapid prototyping
	Measurement and Scanning Technology with 3D Additive Models	Material Science and its application
	Electroless Plating & Laboratory Robotics	Plating of material and role of robotics in HVM
	Manufacturing & Assessment of Stainless-Steel Components	Material Science and properties
2018	Electro and Electroless Nickel Plating on 3D printed Plastic Parts	Coating of metal particles over components
	Supply Chain Management	Flow of materials and products from source to end user
	Fracturing Behavior of Materials	Material properties and behavior
	Carbon Nanotubes and Cellulose Nano crystals	Process, Testing and 3D Modelling
	Lean Manufacturing	Waste elimination, continuous improvement

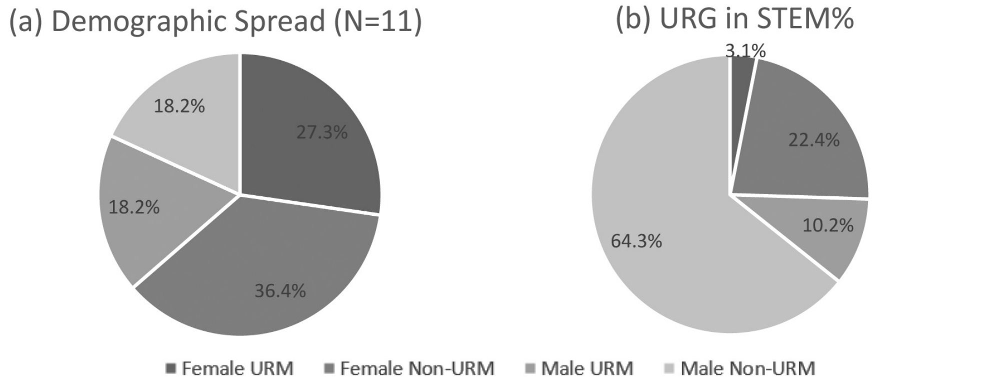

Fig. 2. (a) Demographic information and (b) URG in STEM, 2013 national average: 35 % URG.

disagree" and 5 meant "strongly agree". Fig. 3 depicts the distribution of respondents whose self-efficacy improved, reduced, or remained the same based on pre and post survey scores after the E3 program. In general, self-efficacy scores of the participants improved across the board following the E3 program. Interestingly, self-efficacy expectancies related to use of technology use in the class and the 21st century learning attitude saw some decrease in scores although by a small percentage. This may be due the fact that those teachers might have been already using the modern teaching technologies at their schools. The following sections present the data analysis and results of hypothesis test conducted for the four research questions presented in Table 2.

4.2.1 RQ1: Effect of E3 Program on Perception, Self-Efficacy Beliefs and Outcomes

The first research question (RQ1) is whether or not the teachers' perceptions, self-efficacy beliefs, and outcome expectancies changed significantly after partaking in the E3 program. Because of the smaller sample size, the Wilcoxon signed-rank test was performed on the data. Further, each pair of observations refers to a pre and post enrichment program survey conducted on the same respondent. Thereby, the responses in the pair are not independent but in fact, correlated. Since the Wilcoxon Signed-Rank test is a non-parametric test ideally suited for correlated data, we decided to use it for our study over other competing techniques like the Mann-Whitney test [66].

The *p*-values obtained after performing the Wilcoxon Signed-Rank test on each of the seven constructs of the T-STEM survey, comparing the mean scores pre and post E3 program are detailed in Table 4. It shows that there were two areas (Teaching Technology Efficacy (A) and Beliefs, and STEM Career Awareness (G)) in which the hypothesis tests were found significant at 95% confidence level (see Table 4). Note in Table 4 and in other results tables, p-values significant at the 95% confidence level are bolded. This implies that the teachers' efficacy beliefs regarding technology improved significantly after they completed the E3 program, thereby making the program a success However, it may be noted that there was positive

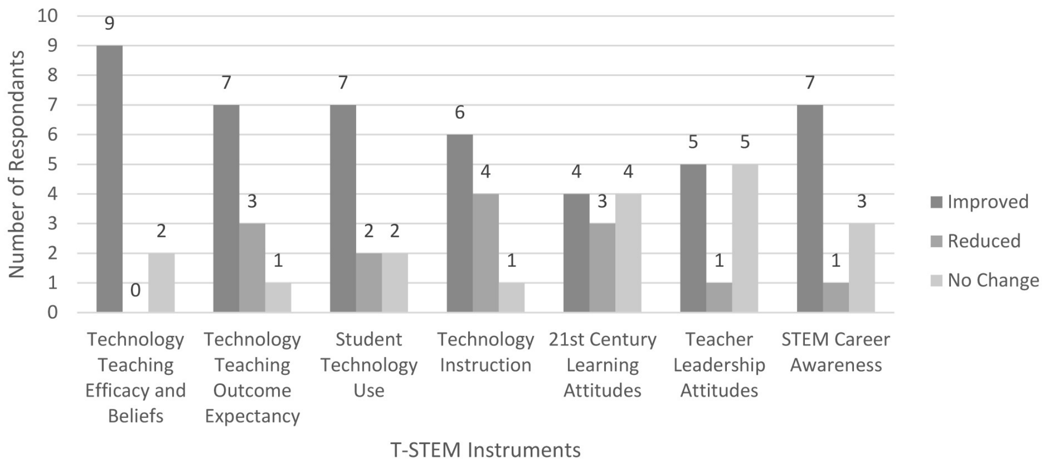

Fig. 3. Changes observed in the pre- and post E3 survey scores.

Table 4. Survey mean score (Overall comparisons)

Section	A	B	C	D	E	F	G
Pre	3.86	2.76	3.88	3.43	4.64	4.53	4.29
Post	4.27	3.37	4.13	3.89	4.61	4.69	4.79
p-value	**0.009**	0.092	0.109	0.092	0.799	0.400	**0.020**

* Bold type indicate statistically significant at 95% confidence level.

gain in the self-efficacy beliefs and outcome expectancies across all seven T-STEM scale domains.

4.2.2 *RQ2: Effect of Type of Schools on Teacher's Self-Efficacy Beliefs and Outcome Expectancies*

To answer the RQ2 (*Do the teacher's self-efficacy beliefs and outcome expectancies depend on their type of school district?*), the participants were divided into two groups, namely "urban" and "non-urban", based on the locations of their respective schools and conducted a two-sample T-test on the difference of post and pre scores to test for a statistically significant difference. The non-urban group consisted of the teachers in rural and suburban locations as classified by the Texas Education Agency and the city group consisted of the teachers in the city as listed in the school location campus/district type mentioned in the dataset provided [67].

Table 5 shows the mean scores of pre-post E3 program differences in scores for the two groups. According to the results, there was a significant change observed for section E, which is 21st Century Learning Attitudes. In other words, the average gain in score with respect to attitude towards 21st century technology was significantly higher among the urban teachers than that for the non-urban teachers. It should be noted that the gain for the urban teachers as a result of the program was consistently higher for almost all T-STEM constructs.

4.2.3 *RQ3: Effect of Gender on Teacher's Self-Efficacy Beliefs and Improvement in Outcomes Expectancies*

The results for the pre and post scores showed that the pre and post-program differences were not statistically significant for any of the constructs between male and female participants. This suggests that the improvement in post score from pre score does not depend on the gender at a 95 % confidence level (Table 6).

4.2.4 *RQ4: Effect of Diversity on Teacher's Self-Efficacy Beliefs and Improvement in Outcomes Expectancies*

To assess the effect of ethnicity on teachers' self-efficacy beliefs, the teachers were divided into URM and Non-URM groups and their survey scores were analyzed. Table 7 shows the mean scores of post-pre score differences for URM/Non-URM groups and p values associated with the T-STEM instruments. The results for the pre and post scores showed that the two groups had significantly different changes

Table 5. Mean of (Post-Pre) Scores for type of school district based groups

Section	A	B	C	D	E	F	G
Urban	0.4	0.5	0.6	0.3	0.4	0.2	0.7
Non-Urban	0.3	0.3	0.4	0.3	–0.2	0.0	0.3
p-value	0.745	0.738	0.806	0.992	**0.049**	0.229	0.162

* Bold type indicate statistically significant at 95% confidence level.

Table 6. Mean of (Post-Pre) Scores for Gender groups

Section	A	B	C	D	E	F	G
Female	0.4	0.3	0.7	0.4	0.1	0.2	0.4
Male	0.3	0.6	0.2	0.1	0.0	–0.1	0.4
p-value	0.857	0.556	0.340	0.318	0.773	0.095	0.977

Table 7. Mean of (Post-Pre) Survey Scores for ethnicity groups

Section	A	B	C	D	E	F	G
URM	0.28	–0.15	0.38	0.24	0.28	0.15	0.50
Non-URM	0.61	0.40	0.50	0.45	–0.42	–0.11	0.25
p-value	0.254	0.354	0.793	0.549	**0.049**	0.225	0.454

* Bold type indicate statistically significant at 95% confidence level.

for the 21st Century learning attitudes. Non-URM participants had a decrease in this construct while URM had an increase in this construct after the E3 program.

4.2.5 RQ5: Effect of E3 Program on Manufacturing Self-Efficacy and Beliefs of Teachers

Before taking part in the E3 program, in addition to T-STEM survey, the teachers also completed a survey on manufacturing beliefs. The manufacturing survey included nine questions covering different types of beliefs that are sometimes associated with manufacturing [68] (see Table 8). The survey response was designed as 1–5 Likert Scale (1 being Strongly Disagree and 5 being Strongly Agree). These results showed that the teachers that came into the program generally did not hold negative views about manufacturing.

After completing the E3 program the teachers were asked to fill out a feedback survey alongside completing the T-STEM posttest assessment. The respondents of the program had significant positive response at the end of the program related both to program content and to manufacturing. Thus, the responses provided by the teachers indicate that their experience with the E3 program was extremely positive.

4.3 One-Year Follow-up

Approximately one year after their summer E3 program, each participant was asked to submit a report on the implementation of their lesson plans that they had created during the E3 program. In other words, the follow-up survey was in the form of a report. There were ten questions asked of each teacher to be included in their follow-up report. These questions involved both quantitative and qualitative responses. Quantitative response questions included pre and post self-efficacy score of students about engineering and engineering career whereas qualitative questions included teachers 'feedbacks on the implementation of the curricular activities in their classrooms. For example, depending upon a project type that a teacher may have assigned, engineering self-efficacy assessment tool included questions like ''what kind of jobs a manufacturing engineer do'', ''what type of problems an engineer can solve'', et cetera. Students were also asked about their college plans and their likelihood of choosing an engineering major. In addition to the common questions, the teachers also conducted pre- and post-self-efficacy scores of students in a specific field such as nano-technology, industrial distribution, and fracturing behavior of a material. On the other hand, the qualitative feedbacks included answers to such questions as: (1) what is the association of their lesson plans with TEKS (Texas Essential Knowledge and Skills for Technology Applications); (2) describe their daily instruction plans; (3) teacher's reflection on how well the project went (what worked well and what did not work); (4) from the student's perspective how well the project was received, what challenges they faced, and what did they like about the project; and (5) from teacher's perspective, how would they change the plan to improve for the next class?

While over 90% of the E3 participants responded to one-year follow up, only 6 out of 11 teachers reported that they were able to implement the

Table 8. Teacher's Beliefs about Manufacturing

Belief in Manufacturing	Response Mean Score
Manufacturing is more art than science	2.0
Manufacturing is limited to automotive and electronics	1.8
Manufacturing is too early to introduce to high school students	1.6
Concepts are difficult to fit in high school curriculum	1.8
The workshop may be too technical	1.6
Teachers will have enough resources to include the training module to high school students	2.4
Manufacturing is a dirty job which is why it is difficult to attract high school students	1.4
The manufacturing jobs are limited to Texas	1.4
The students need to wait till college to learn about manufacturing	1.0

Table 9. Overall program assessment data

Experience in the course	Response Mean Score
Materials were very hands-on and easy to visualize the process	5.0
Learned a lot about high value manufacturing and engineering	5.0
Perception about manufacturing have changed after this workshop	4.6
Manufacturing is a science therefore it fits with my STEM course	4.6
Manufacturing curriculum can be introduced to high school students	4.8
Motivation to attend more workshops to enhance my knowledge	5.0

lesson plans. The others were either not able to implement due to lack of resources, did not respond, or moved to new position. The follow-up reports showed that they implemented their lesson plans and conducted pre- and post-test to assess the impact of their lesson plans. The teachers who responded to the follow up survey included the topics related to electro and electroless Nickel plating on 3D printed plastic parts, engineering design and presentation, material sciences and properties, and lean manufacturing and industrial distribution. The teachers adopted the methodology to first identify the knowledge level and exposure to the respective STEM topic by taking an assessment. Based on the exposure level of the students in their classes, the teachers paced the curriculum and promoted communication, collaboration, research, and information fluency. One of the teachers organized a poster presentation session at the end of the project topic to analyze the reflection of team's analysis, learning objectives and their data analysis approach. A common challenge identified by more than 50% of the respondents was about the problem of making the content relatable for the high school students. They pointed out challenges connecting the coursework with high school engineering courses and making it interesting for students. Overall, all of the responded reported that their post-project efficacy or test scores improved. On the other hand, as expected, the level of successful implementation attained varied by the project type. For example, one teacher reported that, because of their prior knowledge in chemistry, students were able to follow the nickel plating project easily. In another case, the teacher reported that he had to make several modifications during his engineering design project because of student's lack of measurement skills.

On the reflection question, majority of teachers mentioned time as a major constraint. They all used different mode of instructions such as "*lecture, guided practice, small group, and independent practice*". They also reported that not only their students post project assessment scores improved across the projects, but also students were more interested in learning more about those topics. Lastly, following quotes summarizes their recommendation for their peers who might want to implement similar projects in future: "*Start early as possible if you have all your supplies*"; "*Evaluate after each lesson*"; "*Plan ahead / Self prepare – 3–4 week before you start the lesson*"; and "*Use of Google classroom*". As can be gleaned from these quotes, the overall emphasis was on proper planning, use of technology, and providing students with sufficient time on these projects so they can digest the content and adequately implement the assigned tasks.

5. Discussion of Results and Implications

This project examined the impact of providing high school teachers enrichment experiences in advanced manufacturing. The topics which were covered in the enrichment experiences included electro and electroless nickel plating, fracturing behavior of advanced high strength steel (AHSS), how to incorporate cellulose nanocrystals with carbon nanotubes by vacuum assisted resin transfer molding, shape memory polymers (SMPs), supply chain management, quality assurance, and industrial distribution and Rapid Prototyping. The E3 program had 82% of participants from groups traditionally underrepresented in STEM. Eighty percent of the participants were extremely satisfied with the program's hands-on approach.

The post E3 survey shows an increase for mean scores for technology teaching efficacy and beliefs and STEM career awareness for all teachers surveyed. Teachers also believed that that manufacturing was more science than art, as well disagreed on the public perception of manufacturing such as "limited to automotive and electronics", and "too early to introduce in high school". The comparison of pre-post survey scores showed a significant difference in the scores for the 21st Century learning attitudes between urban and non-urban school teachers. This may be due to the difference in the size of teaching institutions and number of students in the urban and non-urban groups. Prior research suggests that the gap in self-efficacy improvement in the teachers (based on school location) can be done via training programs [69]. On comparing the gender and ethnicity aspects there was no significant change observed for pre and post survey score differences between various groups.

Furthermore, the challenge and enablers identified in the follow up survey can also help future intervention programs and K-12 teachers to prioritize making content relatable and ensuring that support systems are in place to provide teachers with any necessary assistance during implementation. The one year follow up survey data showed that there was an overall improvement in the student grades and learning when teachers implemented the classroom activities and learning materials that they had prepared during the E3 program. The participating teachers also recommended to start/plan early for a successful deployment of the curriculum and promote learning. Overall, the responses given by the teachers indicate that their experience with the E3 program was extremely positive and the survey shows the effectiveness in improving the scores with respect to technology teaching efficacy and beliefs, outcome expectancy, student technology use, leadership attitudes and STEM career awareness.

6. Conclusion and Future Work

The objective of this work was to evaluate the impact of the E3 program on the participating teachers and determine whether it resulted in improving their technology self-efficacy beliefs and attitudes and STEM career awareness. For that purpose, the teachers were asked to complete pre-program surveys (prior to participating in the E3 program) and post-program surveys (after completing the E3 program) based on the T-STEM instrument [52]. The T-STEM survey consisted of seven constructs; the test was carried out for each of the sections individually. Their scores were then compared using a Wilcoxon Signed-Rank test to determine if the mean response changed. It was found that for two sections namely, for technology teaching efficacy and beliefs and STEM career awareness, the post-program response was significantly better than the pre-program ones. This implied that the technology teaching self-efficacy beliefs of the schoolteachers improved significantly after participating in the E3.

This research also examined the effect of gender, underrepresented minority status, and school type of the on the improvement of teachers' self-efficacy. It was found that the improvement difference in self-efficacy beliefs was statistically significant between urban and non-urban teachers with respect to the 21st century learning attitudes. The results showed that teachers did not harbor some of the negative stereotypes associated with manufacturing. Apart from being able to improve the teachers' attitudes and efficacy beliefs, the E3 program also received positive feedback from the participating teachers on the overall program. They all agreed that their perceptions regarding manufacturing changed significantly after completing the E3 program and expressed their eagerness towards attending similar workshop programs in the future for enhancing their knowledge.

Although this study has revealed important insights for educators and administrators with respect to impact of an enrichment experience on teacher's self-efficacy, it has few inherent imitations that must be accounted for before generalizing the findings. First, the sample size of the study was limited. Second, although the teachers and school represented in this study were very diverse both demographically and geographically, all teachers and schools were from the state of Texas only. Lastly, while this study included a follow up activity with respect to teacher's progress in implementation of learning modules that were developed during the E3 program, the study did not have a data on how many high school students did eventually join engineering programs following their graduation. Therefore, to broaden the generalization of the results, it would be recommended to conduct a follow up study with larger sample size and a longitudinal study that tracks the student college enrollment and their choice of majors/ careers.

Acknowledgements – This material is supported by the National Science Foundation under DUE Grant Numbers 1501952 and 1501938. Any opinions, findings, conclusions, or recommendations presented are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

1. National Association of Manufacturers, 2019 United States Manufacturing Facts, https://www.nam.org/state-manufacturing-data/2019-united-states-manufacturing-facts/, Accessed 05 March 2020.
2. C. Javdekar, E. Watson, V. Kapilow, M. Bograd, P. Boyer,I. Zeid and D. Claire, Closing the advanced manufacturing talent gap, *Procedia Manufacturing*, **5**, pp. 1197–1207, 2016.
3. C. Giffi, M. D. Rodriguez and S. Mondal,A look ahead: How modern manufacturers can create positive perceptions with the US public, https://www2.deloitte.com/us/en/pages/manufacturing/articles/public-perception-of-the-manufacturing-industry.html, Accessed 18 February, 2020.
4. C. Giffi, P. Wellener, B. Dollar, H. A. Manolian, L. Monck and C. Moutray, The jobs are here, but where are the people?, Deloitte, https://www2.deloitte.com/us/en/insights/industry/manufacturing/manufacturing-skills-gap-study.html, Accessed 05 March 2020.
5. M. Levinson, Job creation in the manufacturing revival, Congressional Research Service, http://www.fas.org/sgp/crs/misc/R41898.pdf, Accessed 10 March 2020.
6. L. C. Benson, K. Becker, M. M. Cooper, O. H. Griffin and K. A. Smith, Engineering education: departments, degrees and directions, *International Journal of Engineering Education*, **26**(5), pp. 1042–1048, 2010.
7. Report to the President on capturing domestic competitive advantage in advanced manufacturing, 2012, https://www1.eere.energy.gov/manufacturing/pdfs/pcast_july2012.pdf, Accessed 10 March 2020.
8. G. T. Spak, US advanced manufacturing skills gap: Innovative education solutions, *Social and Behavioral Sciences*, **106**(1), pp. 3235–3245, 2013.
9. Report to the President on ensuring american leadership in advanced manufacturing, 2011, https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-advanced-manufacturing-june2011.pdf, Accessed 10 March 2020.
10. Job openings, hires, and quits reach historic highs in 2018, *Monthly Labor Review*, U.S. Bureau of Labor Statistics, https://www.bls.gov/opub/mlr/2019/article/job-openings-hires-and-quits-reach-historic-highs-in-2018.htm, Accessed 10 March 2020.

11. Emerson Survey: 2 in 5 Americans believe the STEM worker shortage is at crisis levels, https://www.emerson.com/en-us/news/corporate/2018-stem-survey, Accessed 10 March 2020.
12. A. P. Carnevale, N. Smith and M. Melton, *STEM: Science Technology Engineering Mathematics*, Center on the Education and Workforce, Georgetown University, 2011.
13. J. Rothwell, The hidden STEM economy, *Metropolitan Policy Program at Brookings*, 2013. https://www.brookings.edu/wp-content/uploads/2016/06/TheHiddenSTEMEconomy610.pdf Accessed 10 March 2020.
14. S. C. Beering, P. D. Galloway, M. R. Abbott and D. E. Arvizu, Preparing the next generation of STEM innovators: Identifying and developing our nation's human capital, *National Science Board*, pp. 10–33, 2010.
15. *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*, Washington DC: National Academy Press, 2011.
16. L. S. Nadelson, J. Callahan, P. Pyke, A. Hay, M. Dance and J. Pfiester, Teacher STEM perception and preparation: Inquiry-based STEM professional development for elementary teachers, *The Journal of Educational Research*, **106**(2), pp. 157–168, 2013.
17. S. M. Dougherty, The effect of career and technical education on human capital accumulation: Causal evidence from Massachusetts, *Education Finance and Policy*, **13**(2), pp. 119–148, 2016.
18. M. A. Gottfried, R. Bozick, E. Rose and R. Moore, Does career and technical education strengthen the STEM pipeline? Comparing students with and without disabilities, *Journal of Disability Policy Studies*, **26**(4), pp. 232–244, 2014.
19. J. S. Plasman and M. A. Gottfried, Applied STEM coursework, high school dropout rates, and students with learning disabilities, *Educational Policy*, **32**(5), pp. 664–696, 2016.
20. M. T. Wang and J. L. Degol, Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions, *Educational Psychology Review*, **29**(1), pp. 119–140, 2017.
21. Y. Xie, M. Fang and K. Shauman, STEM education, *Annual Review of Sociology*, **41**(1), pp. 331–357, 2015.
22. A. Bandura, Self-efficacy: Towards a unifying theory of behavioral change, *Advances in Behaviour Research and Therapy*, **1**(4), pp. 139–16,1978.
23. M. Tschannen-Moran and A. W. Hoy, Teacher efficacy: Capturing an elusive construct, *Teaching and Teacher Education*, **17(**7), pp. 783–805, 2001.
24. J. E. Maddux, L. Brawley and A. Boykin, Self-efficacy and healthy behavior: Prevention, promotion, and detection, *Self-Efficacy, Adaptation, and Adjustment: Theory, Research, and Application.*, pp. 173–202,1995.
25. A. B. Dellinger, J. J. Bobbett, D. F. Olivier and C. D. Ellett, Measuring teachers' self-efficacy beliefs: Development and use of the TEBS-Self, *Teaching and Teacher Education*, **24**(3), pp. 751–766, 2008.
26. F. Pajares, Self-efficacy beliefs in academic settings, *Review of educational research*, **66(**4), pp. 543–578, 1996.
27. M. Tschannen, A. W. Hoy and W. K. Hoy, Teacher efficacy: Its meaning and measure, *Review of Educational Research*, **68**(2), pp. 202–248, 1998.
28. A. W. Hoy and R. B. Spero, Changes in teacher efficacy during the early years of teaching: A comparison of four measures, *Teaching and Teacher Education*, **21(**4), pp. 343–356, 2005.
29. R. M. Allinder, The relationship between efficacy and the instructional practices of special education teachers and consultants, *Teacher Education and Special Education*, **17**(2), pp. 86–95, 1994.
30. C. D. Jerald, Believing and achieving, *Center for Comprehensive School Reform and Improvement*, 2007.
31. F. D. Betoret, Stressors, self-efficacy, coping resources, and burnout among secondary school teachers in Spain, *Educational Psychology*, **26**(4), pp. 519–539, 2006.
32. G. V. Caprara, C. Barbaranelli, P. Steca and P. S. Malone, Teachers' self-efficacy beliefs as determinants of job satisfaction and students' academic achievement: A study at the school level, *Journal of School Psychology*, **44**(6), pp. 473–490, 2006.
33. D. W. Chan, Emotional intelligence and components of burnout among Chinese secondary school teachers in Hong Kong, *Teaching and Teacher Education*, **22**(8), pp. 1042–1054, 2006.
34. S. D. Gibson and H. Myron, Teacher efficacy: A construct validation, *Journal of Educational Psychology*, **76**(4), pp. 569–582, 1984.
35. D. Holzberger, A. Philipp and M. Kunter, Predicting teachers' instructional behaviors: The interplay between self-efficacy and intrinsic needs, *Contemporary Educational Psychology*, **39**(2), pp. 100–111, 2014.
36. M. F. Pajares, Teachers' beliefs and educational research: Cleaning up a messy construct, *Review of Educational Research*, **62**(3), pp. 307–332, 1992.
37. J. C. Jawitz and M. Tshabalala, Why not engineering? The process of career choice amongst South African female students, *Internaitonal Journal of Engineering Education*, **16**(6), pp. 470–475, 2000.
38. A. W. Hoy, Changes in teacher efficacy during the early years of teaching, *Annual meeting of the American Educational Research Association*, New Orleans, LA, April 28, 2000.
39. E. M. Olsen, Helping teachers believe! An investigation into the relationship between principal leadership behaviors, organizational supports, and teacher efficacy belief, University of California,San Diego, 2008.
40. K. L. Wahlstrom and K. S. Louis, How teachers experience principal leadership: The roles of professional community, trust, efficacy, and shared responsibility, *Educational Administration Quarterly*, **44**(4), pp. 458–495, 2008.
41. M. H. Dembo and S. Gibson, Teachers' sense of efficacy: An important factor in school improvement, *The Elementary School Journal*, **86**(2), pp. 173–184, 1985.
42. A. Bandura, *Self-Efficacy: Toward a Unifying Theory of Behavioral Change* (*The Self in Social Psychology*), New York, NY, US: Psychology Press, pp. 285–298,1999.
43. S. B. Jain, A. Mary, J. Stellern and N. Srivastava, Self-Efficacy as a function of attributional feedback, *Journal of School Counseling*, **5**(4), 2007.
44. D. H. Schunk and P. A. Ertmer, Self-regulatory processes during computer skill acquisition: Goal and self-evaluative influences, *Journal of Educational Psychology*, **91(**2), pp. 251–260, 1999.
45. R. A. Duschl, *Restructuring Science Education : The Importance of Theories and Their Development*, New York Teachers College Press, 1990.
46. J. D. Novak, Human constructivism: A unification of psychological and epistemological phenomena in meaning making, *International Journal of Personal Construct Psychology*, **6**(2), pp. 167–193, 1993.

47. P. T. Ashton and R. B. Webb, *Making a Difference : Teachers' Sense of Efficacy and Student Achievement*, New York, Longman, 1986.
48. D. Armor, P. Conroy-Oseguera, M. Cox, N. King, L. McDonnell, A. Pascal, E. Pauly and G. Zellman, Analysis of the School Preferred Reading Programs in Selected Los Angeles Minority Schools, Rand Corporation Publication, Report No. R-2007-LAUSD, 1976.
49. A. Brouwers and W. Tomic, A test of the factorial validity of the teacher efficacy scale, *Research in Education*, **69**(1), pp. 67–79, 2003.
50. S. A. Deemer and K. M. Minke, An investigation of the factor structure of the teacher efficacy scale, *The Journal of Educational Research*, **93**(1), pp. 3–10, 1999.
51. A. B. Dellinger, Validity and the review of literature, *Research in the Schools*, **12**(2), pp. 41–54, 2005.
52. Teacher Efficacy and Beliefs toward STEM Survey, Friday Insitue for Educational Innovation, Raleigh, NC, 2012.
53. B. R. Brand and J. L. M. Wilkins, Using self-efficacy as a construct for evaluating science and mathematics methods courses, *Journal of Science Teacher Education*, **18**(2), pp. 297–317, 2007.
54. L. G. Enochs, P. L. Smith and D. Huinker, Establishing factorial validity of the mathematics teaching efficacy beliefs instrument, *School Science and Mathematics*, **100**(4), pp. 194–202, 2000.
55. Y. So Yoon, E. Miles Griffin and S. Johannes, Development of the teaching engineering self-efficacy scale (TESS) for K-12 teachers, *Proceedings of the ASEE Annual Conference*, San Antonio, Texas, June 10–13, 2012.
56. Z. K. R. Avery and M. Edward, Developing effective STEM professional development programs, *Journal of Technology Education*, **25**(1), pp. 55–69, 2013.
57. S. Aydin and Y. Boz, Preservice elementary science teachers' science teaching efficacy beliefs and their sources, *Elementary Education Online*, **9**(2), pp. 694–704, 2010.
58. S. C. Pan and T. Franklin, In-service teachers' self-efficacy, professional development, and web 2.0 tools for integration, *New Horizons in Education*, **59**(3), pp. 28–40, 2011.
59. Program Information: Enrichment Experiences in Engineering, Texas A&M University. https://engineering.tamu.edu/outreach/educator-opportunities/e3/program-information.html, accessed 07 May 2020.
60. J. C. Caliendo, T*he effects of Mentored Problem-based STEM Teaching on Pre-service Elementary Teachers: Scientific Reasoning and Attitudes Toward STEM Subjects*, Ph.D. Thesis, https://ui.adsabs.harvard.edu/abs/2015PhDT........69C, 2015, Accessed on 10 May 2020.
61. R. Likert, S. Roslow and G. Murphy, A simple and reliable method of scoring the thurstone attitude scales, *Journal of Social Psychology*, **5**, pp. 228–238, 1934.
62. P. Shelley and H. Naomi, *Early STEM learning and the Roles of Technologies*, Waltham, MA: Education Development Center, Inc., 2016.
63. C. Hill, *Why So Few? Women In Science, Technology, Engineering, And Mathematics*, AAUW.Org., 2010, https://www.aauw.org/app/uploads/2020/03/why-so-few-research.pdf, Accessed 10 March 2020.
64. J. B. Roach, M. K. Yadrick, J. T. Johnson, L. J. Boudreaux, W. A. Forsythe and W. Billon, Using self-efficacy to predict weight loss among young adults, *Journal of the American Dietetic Association*, **103**(10), pp. 1357–1359, 2003.
65. D. Pekmezi, E. Jennings and B. H. Marcus, Evaluating and enhancing self-efficacy for physical activity, *ACSMs Health Fit Journal*, **13**(2), pp. 16–21, 2009.
66. E. Whitley and J. Ball, Statistics review : Nonparametric methods, *Critical Care*, **6**(6), p. 509, 2002.
67. Campus and district type data search, https://tea.texas.gov/reports-and-data/school-data/campus-and-district-type-data-search, Accessed 10 March 2020.
68. Myth-Busting American Manufacturing, https://mapifoundation.org/economic/myths-may2017-z7z52, Accessed on 15 March 2020.
69. E. O. Durowoju and O. U. A. Onuka, Teacher self-efficacy enhancement and school location: Implication for students' achievement in economics in senior secondary school in ibadan, Oyo State, Nigeria, *Journal of Education and Practice*, **6**(11), 2015.

Vasu Kumar received his BTech in Mechanical and Automotive engineering from Delhi Technological University in 2015. He is a graduate student at Texas A&M University in College Station, Texas, pursuing a master's degree in Industrial Engineering with a focus in statistics and data sciences. He is currently working as a student technician in the Engineering Technology and Industrial Distribution Department under Dr. Bimal Nepal.

Michael D. Johnson received his BS in mechanical engineering from Michigan State University in 1999. Dr. Johnson received his SM and PhD from the Massachusetts Institute of Technology in 2001 and 2004, respectively. From 2004 to 2007 he was a senior product development engineer at the 3M Corporate Research Laboratory in St. Paul, Minnesota. Dr. Johnson joined the Department of Engineering Technology and Industrial Distribution (ETID)at Texas A&M University in 2007; he is currently a professor there.

Bimal P. Nepal, is a Professor and Associate Director of Industrial Distribution Undergraduate Program at Texas A&M University in the U.S. His research areas include distribution and supply chain management, manufacturing, and engineering education. He has BS in Mechanical Engineering from Malaviya National Institute of Technology, Jaipur (India). He received MS and PhD (both in Industrial Engineering) from Asian Institute of Technology (Thailand) and Wayne State University (USA) respectively. He is a member of INFORMS, ASEM, ASEE, and a senior member of IISE.

Gourav Ghoshal received his master's in Industrial Engineering from Texas A&M University in 2019 and BE in Mechanical Engineering from Jadavpur University in 2014. He is currently working as a Quantitative Associate at Wells Fargo.