Increasing Teacher Awareness of STEM Careers

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Abstract

Teacher awareness of STEM careers impacts students as they consider career choices. Researchers examined the effects of teacher professional development and lesson implementation in integrated science, technology, engineering, and math (STEM) on teacher awareness of STEM careers. Study subjects included high school science and engineering/technology teachers participating in a ten-day, 70-hour summer professional development institute designed by the funded project Teachers and Researchers Advancing Integrated Lessons in STEM (TRAILS) to educate teachers in adopting an integrated STEM education model incorporating a community of practice. The study used a quasi-experimental nonequivalent control group design that incorporated an experimental group and an untreated control group with both pretest, posttest, and delayed posttest assessments of non-randomized participants. Researchers analyzed changes in scores on the T-STEM survey of STEM career awareness using cumulative link mixed models (CLMM). STEM career awareness increased for teachers participating in professional development and the degree of change varied by group and assessment time.

Introduction

Concern for improvement in STEM education in numerous countries continues to increase as appeals for a STEM-skilled workforce is critical to meet economic challenges. Educational groups and government agencies in the United States are advocating for more quality integrated STEM curricula and research to increase learning and the pipeline of students entering STEM careers (Autenrieth, Lewis, & Butler-Perry, 2017; PCAST, 2010; US Department of Labor, 2007). Teachers have significant influence on student interest in and understanding of STEM educational pathways and careers (Autenrieth, Lewis, & Butler-Perry, 2017; Brophy, Klein, Portsmore, & Roger, 2008). Perceptions concerning labor and skill deficiencies in the current and future STEM workforce are driving STEM education initiatives and interest globally as employment demand grows and STEM workers retire (Caprile, Palmen, Sanz, & Dente, 2015; English, 2017).

A gap remains in effectively enhancing STEM instruction and researching integrated STEM teacher professional development approaches (Nadelson, Seifert, Moll, & Coats, 2012). This study examined the effects of integrated STEM teacher professional development and lesson implementation on teacher awareness of STEM careers. Nadelson and Seifert (2017) defined integrated STEM education as the incorporation of content and concepts across several STEM disciplines seamlessly, where knowledge and skills of various STEM fields are simultaneously utilized in a problem, project, or task type of context. Integrating math and science teaching is not a novel idea, but integrating STEM disciplines in K-12 education has more recently become a widespread phenomenon (Honey, Pearson, & Schweingruber, 2014). The rationale for this project focus includes the national emphasis for teaching science through engineering design (NGSS Lead States, 2013).

Additionally, many international problems require a collaborative approach by individuals skilled in STEM fields to find and implement effective solutions, yet students' motivation toward STEM learning has declined in many nations (Thomas & Watters, 2015). More research is needed to determine what elements of quality integrated STEM teacher professional development enhance STEM student learning and interest in pursuing careers in STEM fields (Miles, Slagter van Tryon, Mensah, 2015). High-quality teacher professional development enhancing student motivation to pursue careers in STEM fields could help connect workforce needs and student interest (Miles, et al., 2015). Furthermore, few studies have focused on formal in-school contexts rather than after-school and out-of-school STEM education approaches (Honey, et al., 2014).

Purpose of the Study

This research investigated the effect on teacher awareness of STEM careers of several activities: a) incorporating STEM professionals in a community of practice, b) developing integrated STEM instruction, and c) teacher professional development (Kelley & Knowles, 2016). Beyond merely exposing teachers to STEM professionals, this professional development model aims to assist teachers in incorporating a community of practice approach to enhance student learning of STEM disciplines and career pathways. This research seeks to evaluate what elements of teacher professional development increase teachers' awareness of STEM careers to ultimately enhance student pursuit of STEM careers in integrated classroom contexts (Honey, et al., 2014; Miles, et al., 2015).

This study is part of a larger research project, NSF ITEST grant (award #1513248) *Teachers and Researchers Advancing Integrated Lessons in STEM (TRAILS)*, based on a theoretical framework emphasizing scientific inquiry, engineering design, technological literacy, mathematical thinking, and situated learning in a community of practice as an integrated educational approach. Novices and experts work collaboratively together in a community of practice linking STEM content with current practices (Kelley & Knowles, 2016). Combining various pedagogical and learning approaches rather than a single approach, the TRAILS model of integrated STEM education benefits multiple learning styles by providing meaningful contexts.

This research was guided by the question: does teacher awareness of STEM careers and resources increase with participation in integrated STEM education professional development and after implementation of integrated STEM lessons?

Theoretical Framework

This research examines the efficacy of the TRAILS program (Kelley & Knowles, 2016; Figure 1) which was created to leverage science inquiry and engineering design as an approach to promote STEM learning and develop students' technological literacy and mathematical thinking skills. It is significant that each of these approaches are bound by a 'rope' of community of practice, represented here in Figure 1 as the rope in a block and tackle to lift the 'load' of situated STEM learning. The analogy of a block and tackle pulley system allows for these various pedagogical approaches to represent each part in the system working harmoniously to promote STEM learning.

The TRAILS program purposefully established a community of practice of educators, researchers, and community corporate partners to help students and teach-

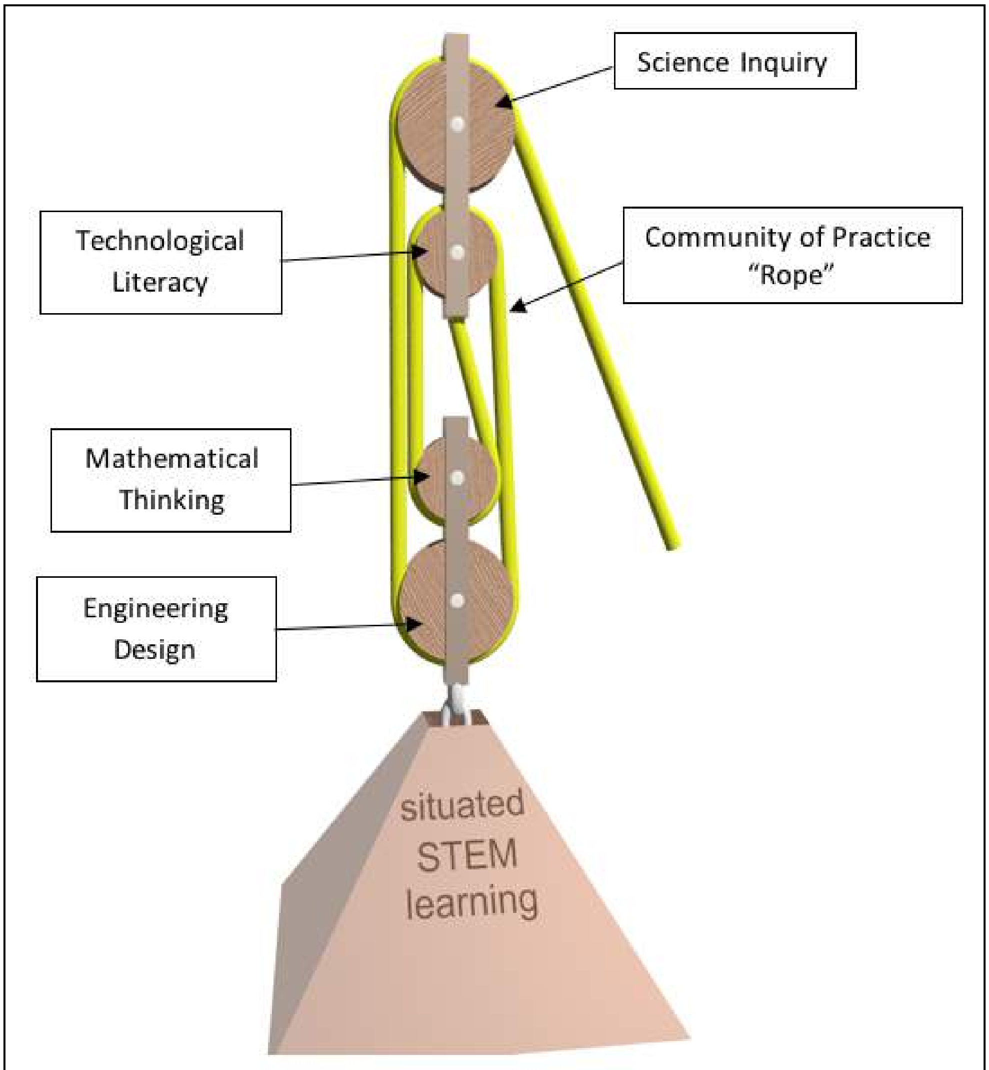

Figure 1. Conceptual framework for STEM learning (Kelley & Knowles, 2016, p. 4)

ers understand STEM career pathways in real practice. However, the learning theory of community of practice moves beyond building a network of community partners for outreach efforts. The concept that Lave and Wenger (1991) had in mind was described as *legitimate peripheral participation* and occurs when the real education for students occurs within a community of practitioners to help the student move from a beginner in their understanding of practices, skills, and general knowledge of a subject toward level of expertise as students engage "in a social practice of a community" (p. 29).

> In a community of practice, novices and experienced practitioners can learn from observing, asking questions, and actually participating alongside others with more or different experience. Learning is facilitated when novices and experienced practitioners organize their work in ways that allow all participants the opportunity to see, discuss, and engage in shared practices. (Levine & Marcus, 2010, p. 390)

TRAILS leadership began by inviting experts to present their work at the intersections of advanced manufacturing, STEM research, biomimicry, and education. For example, advanced manufacturing experts featured presentations on additive manufacturing innovations and 3D scanning for inspection and design analysis. The topics provide the teachers with authentic contexts for learning and teaching STEM content and practices (Brown, Collins, & Duguid, 1989; Bruner, 1996; Lave & Wenger, 1991). These STEM experts were provided with TED talk guidelines and asked to give a 20-minute presentation on their career path and work experiences related to integrated STEM, innovation, manufacturing, or research science. The STEM professionals invited covered topics including education, manufacturing, and science (Table 1) during the 2016–2017 academic year.

The community of practice members were challenged to not only share their practices but also highlight their career pathway as well as present current job challenges. STEM professionals share knowledge of emerging STEM fields, thus allowing teachers to provide authentic learning experiences based on real science, technology, and engineering practices. Additionally, this approach seeks to enhance teacher's pedagogical content knowledge and acknowledges these educators as key career path advisors for students. Teachers were encouraged to reach out to these professionals for advice while creating lessons, invite these professionals to be guest speakers in the classroom, and serve on design assessment panels at the end of TRAILS design projects. Teachers were also encouraged to add members of the community of practice with STEM professionals in the towns and cities near their schools. While most STEM practice experts engaged with teachers for 1-2 hours during the professional development (see Table 1), a few visited schools as guest speakers assisting with integrated STEM instruction and activities. STEM educators also assisted teachers in the development of their own lessons and assessments during the professional development.

Specific Community of Practice Examples

The following provides more details about these STEM professional presentations. The presenter on 3D scanning provided an overview of the technology, a demonstration and explanation of how the new technology

STEM Practice Expert	Institution/ Company	STEM Content Knowledge
Professional Development Educator	Buck Institute National Fellow	Project Based Learning expert and authored 21st Century skills rubrics, *Bringing Innovation to Schools*.
Science Educator	Biomimicry Institute	Biomimicry as a context Engineering Design to integrated STEM lessons.
3D Scanning Technologist	Online Resources, Inc.	3D scanning technology explained and industry examples provided.
Technology Educator	Indiana High School	3D printing specialist presenting history and application of additive manufacturing.
Senior Design Engineering Specialist	Caterpillar, Inc.	3D printing to innovate engine generator design and troubleshooting
3D Printing Expert	Frontier Additive Manufacturing	Advancing the additive manufacturing process to print alloys and assess material properties in high-temperature conditions.
Science Educators	Indiana Department of Education	Led teacher discussion on new state science content standards and discussed ways to approach these through integrated STEM education
Entomology Scientist	Purdue University Entomology Department	Entomology related to forensics
Career Counselor	Purdue University Recruiter	STEM career pathways within Purdue Polytechnic Institute
Career Counselor	Ivy Tech Community College Recruiter	Associate degree program pathways in technology careers
Technologist & Educator	Ivy Tech Community College, Program Chair	Design Technology degree programs and STEM career pathways
Entomology Scientist & Educator	Purdue University Entomology Department	Research on the interaction of entomology and crop plants, and technology applications in agriculture

Table 1. Summary of TRAILS STEM Professionals/Educators & Topics

works, showed various applications used in industry, and explained some of the challenges and limits of using 3D scanning. One interesting application involved scanning of race cars to measure whether the vehicles were within the tolerance for the race rules and specifications. This 3D scanning technology can measure accurately to within 0.001 of an inch and then create a color model of the vehicle showing where the vehicle is within the specifications or not. This is what the manufacturing industry calls a go-no-go gauge. This innovative application accurately and quickly measures and models quality control in the racing industry.

3D scanning is also rapidly expanding in manufacturing quality control applications as well. These examples are numerous that shows teachers potential STEM career pathways that they, in turn, can share with their students and invite professionals to present and demonstrate real-world design challenges and applications of this technology in the classroom. The experts within the community of practice engage in career pathway discussions with teachers in authentic STEM contexts and practices (Kelley & Knowles, 2016). This dialogue between teacher and experts allows the teachers to think and reflect upon how to best teach these subjects in authentic ways and mentor students for their future career pathways. STEM educators brought insight in how to help students move along STEM career pathways and how to design integrated STEM curriculum incorporating state standards.

An expert in the auto manufacturing industry featured 3D printed models that were used to troubleshoot problems in corporate manufacturing facilities abroad where communication with non-English speaking colleagues was challenging. This example illustrated how 3D printed models can be communication tools in manufacturing. The model allowed the engineer to illustrate in tangible ways the intricate details of manufactured parts that are otherwise difficult to picture conceptually. 3D printing technology allows for construction of physical models when creating mental models is challenging. These examples show teachers the power of this technology as an educational tool in conceptual thinking, thus, prototyping mental models in physical ways. This manufacturing engineer was provided the opportunity to add 3D printing into his work and discovered a powerful way to collaborate with others and solve engineering design problems.

Research Method

The TRAILS project aims to increase high school student interest in STEM careers (https://polytechnic.purdue.edu/trails) by improving teachers' knowledge of STEM career pathways and practices from experiences and discussions during teacher professional development. High school science and engineering technology education (ETE) teachers participating in the TRAILS project attended a ten-day, 70-hour summer professional development for training teachers in an integrated STEM education model allowing them to cogenerate their own integrated lessons.

The professional development is an intensive teacher training on integrated STEM pedagogies (engineering design, science inquiry, project-based learning). Teachers engaged in an exemplar integrated STEM lesson they implemented later during the school year, allowing them to identify key features of an integrated STEM lesson grounded in 21st-century skills. The key features of TRAILS lesson plans include the following: a.) the science of entomology, b.) biomimicry inspired engineering design challenges, c.) 3D printed design solutions, and d.) science inquiry lessons. In this STEM unit called D-Bait (Designing Bugs and Innovative Technology) students engage in a design activity that links the science of entomology, the study of insects, engineering design, and innovative technology. The D-BAIT unit was created as an introduction to biomimicry through an everyday context. Many students have gone fishing or know an angler; however, a student may never have considered an angler as a scientist. The innovative idea around which to integrate STEM subjects creates an entirely new fishing lure that resembles and behaves like prey found in the natural environment. In this unit, students first learn about entomology and observe how insects behave in fish habitat. After evaluating existing lure designs (benchmarking), students create a prototype of a fishing lure through using the engineering design process and applying knowledge of biomimicry, mimicking an insect that commonly becomes a food source for fish. Using CAD software, students develop a prototype of a lure, printing it on a 3D printer. Students calculate the buoyancy of their prototype to determine if it will float or sink, and then test their prediction by testing the prototype in water. The prototype can also be tested by fishing with it, giving the student further opportunity to evaluate their design effectiveness as fish bait (Knowles, Kelley & Hurd, 2016).

TRAILS teachers then used lesson plan templates to cogenerate their own integrated STEM lesson after going through the exemplar lesson the first week of the professional development. Guided by the state and national standards including NGSS and Common Core, teachers identified core STEM content and how the content is delivered within an engineering design context. One example of a custom lesson created by TRAILS teachers focused on the topic of bee pollination and robotics. This unit featured photosynthesis, energy transfer, food webs, bee behavior, pollination, biomimicry, and robotics. Upon completion of various science inquiry and technology lessons, students are given the engineering design challenge to design a robotic bee (non-flying) to solve pollination problems. The final solution required generating a model to illustrate and simulate the relationship of flower and insect and their role in plant pollination and germination.

Research Design

The research design utilized a quasi-experimental nonequivalent control group approach which compares an experimental treatment group and an untreated control group on non-randomized participants (Ary, Jacobs, Sorensen, & Walker, 2009; Creswell, 2009; Shadish, Cook, & Campbell, 2002). Three cohorts of teachers are participating in the TRAILS project over three years, one cohort for each academic year. Cohort 1 teachers in the experimental group attended a two-week professional development institute (the treatment) in June 2016 working on integrated STEM lessons which they then implemented in the classroom during the following school year. The control group did not participate in the professional development or implement any integrated STEM lessons from the professional development. Both groups were given a pretest preceding the summer professional development institute. Then, participants in both groups were asked to take the same assessment for a posttest after the completion of the professional development. The *Qualtrics* online survey platform was utilized for disseminating and collecting data on the pretests and posttests. Teachers in both groups were later asked to take the same assessment as a delayed posttest during the school year after the experimental group had implemented TRAILS lessons.

The researchers investigated the effectiveness of the professional development and ongoing support from the community of practice provided to the experimental group. The T-STEM Survey for measuring teacher STEM career awareness, among other constructs, provided an instrument for assessing teacher attitudes using a Likert-type scale (The Friday Institute for Educational Innovation, 2012a). Since Likert-type scores are ordinal, the analysis implemented ordinal regression modeling for determining significant effects of the independent variable. Cumulative link models for matched pairs (cumulative link mixed models [CLMM] in the R software platform *ordinal* package) were developed for determining significant effects (R Core Team, 2016).

Context of the Study

Potential participants submitted an application online, applicants were reviewed, and then selected by the project leadership team based upon criterion described above. Engineering technology education (ETE) teachers also were required to have experience with parametric modeling and access to 3D printing equipment. As much as possible, control group teachers were aligned with experimental group teachers by similar types of courses and school settings. This matching of courses was done to maximize similar experimental and control groups for the research design since the participants are self-selecting and non-random. Participants were required to have at least two years of teaching experience at their current school and to be teaching primarily in physics, biology, or

Participants	Gender	ETE**	Science	Years Teaching*
Experimental	8 male 4 female	6	6	14.3
Control	7 male 3 female	6 (1 also Math)	4	10.6
Total	15 male 7 female	12	10	12.6

*denotes average number of years of teaching experience in cohort
**ETE indicates Engineering and Technology Education

Table 2. Participant Teacher Demographics

engineering technology education. Pairs of teachers from the same school, thus, collaborated on an integrated approach to teaching STEM. In practice, this was not possible for all teachers and schools. Exposing students to the diverse fields of science and engineering technology through these integrated approaches should inform them of the variety of STEM career options. Although the TRAILS program was open and advertised to all schools in the state, the cohort demographic was limited by the teachers who applied, were interested, and available to participate.

Twelve teachers participated in the first cohort of the professional development in June 2016. The group consisted of science (five biology and one physics teacher) and six ETE teachers. The ETE teachers taught Project Lead the Way (PLTW) or similar courses. The control group consisted of six science and four ETE teachers in the same state. The participants came from a variety of high school settings in rural, suburban, and urban regions. Though there was no diversity in ethnicity, the groups represented a broad diversity of age and teaching experience (Table 2). Females represented nearly a third of the total participants. The participants were close in number in science and technology subject areas.

Survey Instrument

The T-STEM Survey (The Friday Institute for Educational Innovation, 2012a) was used for the pretest and posttest assessments. The T-STEM Survey was developed for measuring a variety of constructs including teacher awareness of STEM careers. Science teachers completed the T-STEM Survey for Science Teachers and ETE teachers completed the T-STEM Survey for Technology Teachers. Items concerning awareness of STEM careers use a Likert-type scale on the T-STEM with 1 being "Strongly Disagree," 2 "Disagree," 3 "Neither Agree Nor Disagree," 4 "Disagree," and 5 being "Strongly Agree" (The Friday Institute for Educational Innovation, 2012a). The complete survey employs 83 Likert-scale questions with four items specifically measuring awareness of STEM careers. The Likert-type scale is commonly used in measuring beliefs in educational related studies and other research (Nathan, Tran, Atwood, Prevost, & Phelps, 2010). Bias may exist among the respondents since this data is self-reported (Sekaran & Bougie, 2009). Higher scores are associated with stronger positive beliefs, except in the case of negatively worded items which are reverse scored.

Subscale	Measurement Application
Science (T-STEM Science) or Technology (T-STEM Technology) teaching efficacy and beliefs	Belief in science or technology teaching ability (Teacher Self Efficacy)
Science or Technology teaching outcome expectancy	Belief in the extent to which effective teaching affects student learning in science or technology (Teaching Outcome Expectancy)
Student technology use	Frequency of student technology use during instruction
STEM instruction	How often the respondent uses certain STEM instructional practices
21st century learning attitudes	Attitudes toward 21st century skills learning
Teacher leadership attitudes	Attitudes toward teacher leadership activities
STEM career awareness*	Awareness of STEM careers and where to find resources for further information*

Note: * denotes construct used in this paper as part of the data collection for the TRAILS project. Adapted from *Teacher Efficacy and Attitudes toward STEM (T-STEM) Survey: Development and Psychometric Properties*. (Friday Institute for Educational Innovation, 2012b; Caliendo, 2015).

Table 3. T-STEM Survey Subscale Summary (T-STEM Science & T-STEM Technology)

This T-STEM survey measures several constructs on nine subscales including: a) teacher confidence and efficacy toward STEM, b) the degree to which teachers believe student learning might be increased by effective teaching, c) teacher attitudes about 21st century skills, d) teacher use of STEM instructional practices, e) awareness of STEM careers, and f) student technology use (Friday Institute for Educational Innovation, 2012a, Table 3). A summary of the T-STEM Survey is shown in Table 3 with a description of each subscale and the corresponding construct measured. Though the entire T-STEM survey is completed by the participants for the TRAILS project, this study will focus on the construct for STEM career awareness. For all constructs on the survey, researchers calculated Cronbach's alpha at 0.95 (Friday Institute for Educational Innovation, T-STEM Survey, 2012b), which indicates the survey has good internal reliability (Caliendo, 2015; Tavakol & Dennick, 2011). Permission was obtained for using the T-STEM survey instruments (T. Collins, personal communication, March 26, 2014).

Data Collection

The T-STEM survey was implemented as a pretest and posttest via an online surveying system, Qualtrics, at the start and end of the TRAILS professional development institute, and a delayed posttest after lesson implementation during the school year. The timing of the pretest, posttest, and delayed posttest surveys were coordinated within the experimental and control groups. Codes were assigned to teachers to enter at the beginning of the survey rather than names to match data for statistical analysis and maintain confidentiality.

Approval from the Institutional Research Board (IRB) was obtained from both higher education institutions involved in the study since human subjects participated in the research. The data collection process was presented to teachers in written form before sending links electronically to take the online surveys. Reminders to complete the surveys were sent a second and third time if necessary approximately seven days later and again fourteen days

Participants	(Pretest)	(Posttest)	(Delayed Posttest)
Experimental	12	12	12
Control	10	10*	9**
Total	22 (100%)	22 (100%)*	21 (95%)

*one survey was partially completed–data for the career awareness subscale is missing
**one teacher dropped out of the study in the control group

Table 4. Participant Survey Completion

after the initial survey link was emailed (Couper, 2008; Dillman, Tortora, & Bowker, 1999). Nearly all participants completed responses to the survey shown in Table 4 (Knowles, 2017).

Data Analysis

Changes in STEM career awareness from the TRAILS professional development were tested with cumulative link mixed models. Effect size measures were calculated using Cliff's Delta for ordinal data to examine the magnitude of the effect for significant differences. Previous studies have used paired t-tests for detecting group differences. T-tests are based on comparing means between groups which is appropriate for continuous data, but not for ordinal data (e.g. Likert scales) which does not follow an interval scale. Mangiafico (2016) emphasized that Likert data is often treated as interval or ratio data in statistical analysis, but should be considered ordinal data since the Likert scale data is not equally spaced. For example, the distance between a 1 ("strongly disagree") and 2 ("disagree") is not essentially equal to the distance between a 4 ("agree") and 5 ("strongly agree"). Following the recommendation of Mangiafico (2016) this study used ordinal regression with a cumulative link model (CLM) to detect differences in Likert scores. This was implemented within the R environment (R Core Team, 2016) using the *ordinal* package (Christensen, 2015; Mangiafico, 2016). Descriptive ordinal statistics for the STEM career awareness construct are calculated for Likert scores including the minimum, first quartile, median, third quartile, and maximum values (Knowles, 2017).

Pretest	Experimental	Median	4
		Minimum	2
		Q1	3
		Q3	4
		Maximum	5
Pretest	Control	Median	4
		Minimum	3
		Q1	4
		Q3	5
		Maximum	5
Posttest	Experimental	Median	4
		Minimum	3
		Q1	4
		Q3	5
		Maximum	5
Posttest	Control	Median	4
		Minimum	2
		Q1	4
		Q3	5
		Maximum	5
Delayed Posttest	Experimental	Median	4
		Minimum	3
		Q1	4
		Q3	4
		Maximum	5
Delayed Posttest	Control	Median	4
		Minimum	3
		Q1	4
		Q3	5
		Maximum	5

Table 5. Descriptive Ordinal Statistics by Test and Group

Cumulative link models (CLM), or in this study for matched pairs, the CLMM (cumulative link mixed model in the R *ordinal* package) function was used for determining significant effects (Mangiafico, 2016). The CLMM function models repeated measures, as in this study when measures are taken at three points in time (pretest, posttest, & delayed posttest). However, it is difficult to test for differences at three points in time and in two different groups in this case. Therefore, to test for significant differences in groups (control and experimental) and measurement times (pretest, posttest, and delayed posttest), the pretest and posttest ordinal regression models were compared using an ANOVA test (Mangiafico, 2016). Then, the posttest and delayed posttest were compared and finally the pretest and delayed posttest were matched in the same way.

The threshold significance or alpha level was set to 0.05, which is commonly used in educational and social science studies (Cumming, 2012; Krzywinski & Altman, 2013). At times a small sample size and low power can fail to detect a significant effect when one may in fact exist. However, matching data pairs using the CLMM function in the R environment provides a powerful test for detecting significant effects. The CLMM may provide insight into what other factors could be influencing measured changes since multiple independent variables can be introduced into the analysis, such as teacher subject area in this study (Knowles, 2017). Ideally a larger sample size would be used to increase statistical power, however significant differences were detected using the CLMM function analysis. The TRAILS teacher professional development was constrained by funding for a maximum of fifteen participants, while the control group was limited to ten teachers. Future teacher cohorts involved in the TRAILS project will provide a larger sample size but are beyond the timing of this current work.

While statistical significance is important for hypothesis testing, the magnitude of an effect or differences in distributions is not clearly conveyed by p-values (Mac-

Teacher Group	Assessment Groups and Times Compared: Pretest/ Posttest Control	Posttest/ Delayed Control	Pretest/ Delayed Control	Pretest/ Posttest Experimental	Posttest/ Delayed Experimental	Pretest/ Delayed Experimental
Science & Engineering Technology Teachers	n.s.	n.s.	n.s.	0.001	n.s.	0.001
Science Teachers	n.s.	n.s.	n.s.	0.001	0.01	0.001
Engineering Technology Teachers	0.05	0.01	0.01	n.s.	0.05	n.s.

Note: Delayed=Delayed Posttest, "n.s." indicates no significant difference found at alpha =0.05. The values in the table cells represent the p-values for the corresponding groups compared.

Table 6. Summary of p-values for Groups and Assessments Compared

beth, Razumiejczyk, & Ledesma, 2010). The effect size measure, Cohen's d, has often been utilized in behavioral sciences and education studies for a measure of the magnitude of a significant effect (Coe, 2002). However, Cohen's d is more appropriately applied to data that is normal and homogenous in behavioral variance (Macbeth, et al., 2010). Another effect size measure, Cliff's Delta, was created specifically for non-normal and asymmetric distributions, and provides a more powerful effect size measure than Cohen's d for ordinal data. Cliff's Delta is recommended for analysis of ordinal data such as Likert scale scores. The effect size measure Cliff's Delta analyzes the overlap between two group distributions (Macbeth, et al., 2010). Cliff's Delta is calculated in the R software environment using the *effsize* package for STEM career awareness measured in this study (The R Core Team, 2016).

Results

Descriptive ordinal statistics for teacher awareness of STEM careers were calculated for participants (Table 5) separated by experimental and control groups for each assessment time (pretest, posttest, and delayed posttest). A median Likert score of 4 in both the experimental and control groups on the pretest indicate the groups were similar in STEM career awareness. Again, a median Likert score of 4 was found for the posttest and delayed posttest. No changes were seen in the median scores for the groups across the three points in time for the assessments, though changes in minimum, first quartile, third quartile, and maximum scores vary slightly across groups and times.

Significant effects of independent variables (teacher group and subject area) were detected using the CLMM in pretest, posttest, and delayed posttest scores in the experimental group that participated in professional development for teacher awareness of STEM careers. The experimental group was further analyzed by teacher subject area. Science teachers significantly increased in their STEM career awareness ($\alpha = 0.05$, $n = 6$, $p = 0.001$). Additionally, significant differences were found in the control group data in the ETE teacher group only ($\alpha = 0.05$, $n = 6$, $p = 0.05$ and 0.01). See Table 6 for a summary of the p-values for groups compared and assessment times. Though TRAILS professional development promotes a partnership between science and ETE teachers, results show there is a greater impact on science teachers in the construct of STEM career awareness. Although the cohort 1 sample size was small, data will be collected on a second and third cohort in the TRAILS project.

Effect sizes were calculated for STEM career awareness when significant differences were detected for comparing the pretest and posttest, the posttest and delayed posttest, and pretest and delayed posttest. Cliff's Delta is calculated on a scale from negative one to positive one, comparing the amount of overlap of two distributions. Effect sizes are summarized below in Table 7 for all of the cases where significant differences in group scores were detected. An effect size of 0.1-0.3 indicates a small effect, though significant, meaning the score distributions for each group compared have a fair amount of overlap. A medium effect size ranges from 0.4-0.6, and a large effect size is greater than 0.7, indicating little overlap between group distributions compared (The R Core Team, 2016).

For STEM career awareness in the experimental group, a medium effect size of 0.4 was determined when comparing the pretest and posttest scores, and a smaller effect size of 0.3 was found in the pretest and delayed posttest scores (Table 7). This reveals a fairly significant effect and difference in score distributions in the experimental group when comparing pretest and posttest, and pretest and delayed posttest scores. A much larger effect size was calculated when only comparing science teacher scores. A large effect size of 0.8 was determined when comparing the experimental science teacher pretest and posttest score distributions. However, a drop in the magnitude of the effect was observed from the posttest to the delayed posttest, which was measured later in the school year. This resulted in a medium effect size measure of 0.6 when comparing experimental science teacher pretest and delayed posttest scores for STEM career awareness. Where p-values revealed significant differences in the control group data, the effect size measures were negligible or negative, indicating a large amount of overlap exists in the distribution of scores and also a decrease in the Likert scores for the control group comparing the pretest and posttest, and then the posttest to the delayed posttest.

Group *Experimental*	Pretest/Posttest	Posttest/Delayed Posttest	Pretest/Delayed Posttest
Science & ETE Teachers	0.4 (medium)	n.s.	0.3 (small)
Science Teachers	0.8 (large)	-0.3 (small)	0.6 (medium)
ETE Teachers	n.s.	negligible	n.s.
Group *Control*	Pretest/Posttest	Posttest/Delayed Posttest	Pretest/Delayed Posttest
Science & ETE Teachers	n.s.	n.s.	n.s.
Science Teachers	n.s.	n.s.	n.s.
ETE Teachers	Negligible	-0.4 (medium)	-0.2 (small)

Note: Effect size values are rounded to the nearest tenth, "n.s." indicates no significant difference found at alpha =0.05, and ETE indicates Engineering and Technology Education Teachers

Table 7. Effect Sizes by Group and Time of Assessment

Discussion

The research results suggest that TRAILS professional development had a greater impact on STEM career awareness for science teachers than ETE teachers. Several variables could influence these results. For instance, cohort 1 may have consisted of ETE teachers more informed about STEM careers, or ETE teachers received prior training that addressed STEM careers. Some ETE teachers are trained in *Project Lead the Way* curriculum that highlights STEM career profiles within textbooks and curriculum documents. Science teachers may have less experience learning about STEM careers outside of the science field. TRAILS professional development featured many engineering and technology topics. Furthermore, the concept of teaching and learning in a community of practice incorporating STEM professionals into the classroom instruction including teaching, sharing STEM career practices, and design evaluation, may be an unfamiliar approach, especially for science teachers.

Though the sample size of teachers in this cohort was relatively small and the results have limited generalizability, the TRAILS professional development appears to have a significant impact on teachers in STEM career awareness. Reviewing the data, the pretest experimental group Likert scores reflect a high STEM career awareness prior to professional development, yet significant growth was found in the posttest results. These findings may reflect the nature of a self-selecting participants bringing their prior motivation, experience, and interest in STEM fields. It is challenging to have an impact on high achieving participants because there is not much room for growth. Teachers in the TRAILS project experienced significant growth in this construct despite this limitation, providing additional evidence this professional development approach was effective.

Implications

As STEM education researchers and professional developers continue to create learning opportunities for teachers, the construct of STEM career awareness should be a focus for improvement. The TRAILS program revealed that providing a platform for STEM professionals to speak directly with teachers and highlight their practices as well as challenges, helped improve teachers' awareness of STEM workforce needs. Additionally, STEM professionals were able to share day-to-day problems in manufacturing, research, and technological development that are overcome using STEM knowledge and skills. These real-world examples were utilized by teachers to help them develop authentic STEM learning experiences connected to current STEM practices. These efforts to engage STEM professionals with STEM teachers was an approach to address the NGSS (NGSS Lead States, 2013) vision to teach students a) shared practices across STEM fields; b) locate crosscutting concepts; and c) engage in authentic engineering design challenges. Each of these professional development approaches requires building and maintaining a community of practice within STEM professionals.

The findings from TRAILS cohort 1 data has helped the leadership team plan more effectively for cohort 2, offered summer 2017. TRAILS summer professional development 2017 increased the number of community of practice speakers by one-third, responding to these findings as continued opportunity for improvement in STEM career awareness. It is important to note that all speakers were challenged to practice their talks, were provided with TED talk guidelines, as well as prompted to specifically talk about problems they encountered in their day to day work and how these problems are addressed using STEM knowledge. These guidelines were deemed important to help speakers remain focused on information relevant to educating K-12 students and increasing teachers' awareness of STEM career pathways.

Conclusions

A significant impact on teachers' awareness of STEM careers was measured after professional development. Additional research will be done on a second and third cohort over the next two years as part of the TRAILS project. Though data collection is ongoing, preliminary results from Cohort 2 (2017-18) reveal similar results on the impact of professional development on STEM career awareness. If similar results are obtained for these additional teacher cohorts, this will provide greater evidence that this approach to professional development is in fact having a significant impact on teacher STEM career awareness. Furthermore, data is being collected on high school students in these courses taught by teachers in both the experimental and control groups. One of the goals of the TRAILS project is to increase student interest in STEM career educational pathways and careers. If this is in fact one of the outcomes observed from this project, then this type of integrated STEM model and curriculum could help to increase the pipeline of students choosing STEM careers to fill the demand in the United States and possibly other nations.

Recommendations

Based upon the findings from this research, the authors would like to make the following recommendations:

1. Feature STEM professionals as speakers for teacher professional development, allowing them to address workforce needs and provide practical STEM problem-solving contexts.
2. Challenge teachers to create learning experiences that are authentic to current STEM practices and provide a link to what students learn in class to what is occurring in STEM fields.
3. When field-trips to manufacturing facilities, science research labs, or university labs are not possible, teachers can use video platforms such as http://www.spark101.org/ to feature professional career profiles and promoting STEM career pathways.
4. Encourage teachers to use STEM professionals on advisory boards, invite them to the classroom as guest speakers, and use these professionals as evaluators on student engineering design projects.
5. Engage STEM professionals as key members of the STEM community of practice by inviting the professionals to add to science inquiry class discussions, critique design ideas, probe challenging questions for investigation, and seek content expert advice to overcome challenges. These STEM professionals can be key educators in the community of practice.

References

Autenrieth, R., Lewis, C., & Butler-Perry, K. (2017). Long-term impact of the enrichment experiences in engineering (E^3) summer teacher program. *Journal of STEM Education 18*(1), 25-31.

Ary, D., Jacobs, L., Sorensen, C., & Walker, D. (2014). *Introduction to research in education* (9th ed.). Belmont, CA: Wadsworth.

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

Brown, J.S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Bruner, J. (1996). *The Culture of Education*. Cambridge, MA: Harvard University Press.

Caliendo, J. (2015). *Pre-service elementary teachers: Scientific reasoning and attitudes toward STEM subjects* (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 3706494).

Christensen, R.H. (2015). *Analysis of ordinal data with cumulative link models-estimation with the R-package ordinal.* Vienna, Austria: The Comprehensive R Archive Network (CRAN), The R Foundation for Statistical Computing. https://cran.r-project.org/web/packages/ordinal/vignettes/clm_intro.pdf

Coe, R. (2002). It's the effect size, stupid: What effect size is and why it is important. In *Proceeding of the British Educational Research Association Annual Conference.* Exeter, UK.

Caprile, M., Palmen, R., Sanz, & Dente, G. (2015). *Encouraging STEM studies for the labour market (Directorate-General for Internal Policies: European Parliament)*. Brussels, Belgium: European Union. Retrieved from http://www.europarl.europa.eu/RegData/etudes/STUD/2015/542199/IPOL_STU%282015%29542199_EN.pdf.

Couper, M. (2008). *Designing Effective Web Surveys.* Cambridge, N.Y.: Cambridge Press.

Cumming, G. (2012). *Understanding the New Statistics: Effect Sizes, Confidence Intervals, and Meta-Analysis*. New York: Routledge.

Creswell, J. (2009). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (3rd ed.). Los Angeles, CA: Sage.

Dillman, D. A., Tortora, R.D. & Bowker, D. (1999). *Principles of constructing web surveys*. Retrieved from: http://claudiaflowers.net/rsch8140/PrinciplesforConstructingWebSurveys.pdf

English, L. (2017). Advancing elementary and middle school STEM education. *International Journal of Science and Mathematics Education, 15*(1), 5-24.

Friday Institute for Educational Innovation. (2012a). *Teacher Efficacy and Attitudes toward STEM Survey (T-STEM)*. Raleigh, NC: North Carolina State University. Retrieved from: http://miso.ncsu.edu/articles/t-stem-survey-2

Friday Institute for Educational Innovation. (2012b). *Teacher Efficacy and Attitudes toward STEM (T-STEM) survey: Development and Psychometric Properties.* Raleigh, NC: North Carolina State University. Retrieved from: http://miso.ncsu.edu/wp-content/uploads/2013/06/T-STEM_FridayInstitute_DevAndPsychometricProperties_FINAL.pdf

Honey, M., Pearson, G., & Schweingruber, H. (Eds.). (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research.* Washington, DC: National Academies Press.

Kelley, T. & Knowles, J. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(11), 1-11. DOI 10.1186/s40594-016-0046-z.

Knowles, J.G. (2017). *Impacts of professional development in integrated STEM education on teacher self-efficacy, outcome expectancy, and stem career awareness* (doctoral dissertation). ProQuest Dissertations & Theses Global. (1933320146).

Knowles, J.G., Kelley, T. & Hurd, B. (September, 2016). Innovate the intersection of entomology and technology. *Technology & Engineering Teacher, 76*(1), 1-7.

Krzywinski, M. & Altman, N. (2013). *Points of significance: Significance, P values and t-tests. Nature Methods. Nature Publishing Group. 10*(11), 1041–1042. Retrieved from: http://www.nature.com/nmeth/journal/v10/n11/full/nmeth.2698.html.

Lave, J., & Wenger, E. (1991). *Situated learning. Legitimate peripheral participation.* Cambridge, England: Cambridge University Press.

Levine, T. H., & Marcus, A.S. (2010). How the structure and focus of teachers' collaborative activities facilitate and constrain teacher learning. *Teaching and Teacher Education, 26* (3), 389–398.

Macbeth, G., Razumiejczyk, E., & Ledesma, R. D. (2011). Cliff's delta calculator: A non-parametric effect size program for two groups of observations. *Universitas Psyhologica, 10*(2), 545-555.

Mangiafico, S. (2016). *Summary and Analysis of Extension Program Evaluation in R, v. 1.2.1.* New Brunswick, NJ: Rutgers Cooperative Extension. Retrieved from: http://rcompanion.org/documents/RHandbookProgramEvaluation.pdf

Miles, R., Slagter van Tryon, P., & Mensah, F. (2015). Mathematics and science teachers professional development with local businesses to introduce middle and high school students to opportunities in STEM careers. *Science Educator, 24*(1), 1-11.

Nadelson, L. & Seifert, A. (2017). Integrated STEM defined: Contexts, challenges, and the future. *Journal of Educational Research, 110*(3), 221-223.

Nadelson, L, Seifert, A., Moll, A., & Coats, B. (2012). i-STEM summer institute: An integrated Approach to Teacher Professional Development in STEM. *Journal of STEM Education, 13*(2), 69-83.

Nathan, M., Tran, N., Atwood, A., Prevost, A., & Phelps, L. A. (2010). Beliefs and expectations about engineering preparation exhibited by high school STEM teachers. *Journal of Engineering Education, 99*(4): 409–426.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press.

President's Council of Advisors on Science and Technology (PCAST). (2010). Prepare and inspire: K–12 education in science, technology, engineering, and math (STEM) for America's future. Washington, DC: Author.

R Core Team (2016). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. Retrieved from: http://www.R-project.org/

Sekaran, U. & Bougie, R. (2009). *Research methods for business: A skill building approach*. Cornwall, U.K.: Wiley.

Shadish, W., Cook, T., & Campbell, D. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. New York: Houghton Mifflin Company.

Tavakol, M. & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education, 2*, 53-55.

Thomas, B. & Watters J. (2015). Perspectives on Australian, Indian and Malaysian approaches to STEM education. *International Journal of Educational Development, 45*(November 2015), 42-53.

US Department of Labor. (2007). The STEM workforce challenge: The role of the public workforce system in a national solution for a competitive science, technology, engineering, and mathematics (STEM) workforce. Washington, DC, Author.

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