STEM Educators: What do they believe about teaching their students?

Anne Lucietto Liza Russell Emily Schott
Purdue University

STEM (Science, Technology, Engineering, and Mathematics) is a frequently discussed subject, as are the students who study it. Not so frequently discussed are the educators that teach and interact with students daily. A great deal of research has been done on the characteristics of STEM students, including who they are, how they learn, and the need to increase the numbers of underrepresented populations. Literature on STEM educators, either by discipline or in general, is not widely available. This is an issue as evidence exists that there is a relationship between an educator's personal beliefs and instructional strategies, which has a direct effect on students. A thorough understanding of STEM educators' beliefs will lead to a better picture of how STEM students around the country are taught.

A survey was developed that includes several open-ended questions intended to further our understanding regarding individual STEM educators' thoughts and beliefs about their students. The survey reached predominantly male educators nearing retirement age who were teaching technology or engineering undergraduates. Of all respondents, educators surveyed received their terminal degree evenly over a time span of 35 years. Word frequency methods often found in a content analysis were used to bring clarity to survey responses. The result of these analyses indicated that many STEM educators believe their students are unique with respect to STEM overall. About half of these educators believe that different STEM majors can be taught similarly, while the other half did not agree or did not respond. This work presents information concerning respondents' thoughts about STEM students and teaching STEM disciplines.

Keywords: *STEM Educators, Students, Belief, Teaching, Survey, Content Analysis*

Introduction

This study was conducted to gain an understanding of STEM educators' thoughts regarding teaching STEM students and the differences in skills necessary for teaching across STEM disciplines. Evidence suggests that there is a significant relationship between educators' individual beliefs and instructional strategies (Kagan, 1992). Additionally, experience and training are often related to educator ability to provide positive reinforcement for students learning new and often confusing subject matter (Ejiwale, 2012; Nadelson et al., 2013). By analyzing STEM educators' training, beliefs and teaching strategies, this study can offer a more holistic view of how their students are being taught.

To understand these educators, an inquiry regarding their instructional strategies for the various disciplines, their perceptions related to STEM students, their training and their self-confidence in teaching between disciplines is necessary. A formal collection of information (in the form of a nationally-distributed survey) was thought to be the best method of attaining this information. The researchers wanted to perform fundamental analysis of STEM educators' perceptions of their students as well as their opinions regarding classroom practice while teaching their subject and other STEM subjects.

Literature Review

A great deal of study has focused on what educators think about the students and subjects that they teach. However, when discipline-specific studies are sought out, most studies are focused on non-STEM disciplines, such as language, literacy (Lynch, 2017), and the arts. Those STEM discipline studies include mathematics (Spillane et al., 2017), engineering, and computing (Rich et al., 2017). However, little research has been done to understand STEM educators specifically despite the work devised to aid educators' teaching abilities (White, 2014), their performance in the classroom (Spillane et al., 2017), and to enhance student engagement (Rich et al., 2017).

STEM educators found in schools throughout the country vary in skill level and education. These variations lead to differing views on STEM students and differing confidence in teaching across disciplines. This ultimately results in varying levels of engagement, motivation, and interest in their STEM discipline. A variety of programs for all types of educators, addressing different skill levels and designed for various levels of experience is evident annually: workshops are usually held during the summer and spring breaks that most educators have in the United States.

These workshops are intended to help educators teach courses using more technology and share new and innovative ways to engage their students (Roberts, 2013). These programs are often evidence-based, focusing on instructor interaction with each other (Lee et al., 2017) and providing a means to measure the effect of an intervention on educators in workshop performance (Watkins & Mazur, 2013). The authors suggest that if an educator does not know the individuals they are working with, it is difficult to teach them how to teach, how to interact, and how to make the subject matter engaging thus encouraging the students to learn and like the teaching content (Hamari et al., 2016), necessitating a need for a comprehensive study of current STEM educators.

STEM, an acronym first used by NSF (National Science Foundation), was initially referred to as METS (mathematics, engineering, technology, and science). The disciplines included in STEM are often subjected to dispute when considering computer science and engineering. In this work, computer engineering is considered an engineering discipline and computer science falls into the technology fields. Clarification is a priority due to this ongoing dispute, and the application and matriculation requirements of each area. The vast majority of computer engineering programs admit through a computer engineering department, while computer science is often considered a technology program as students are admitted through requirements similar to those for other technology students.

This grouping of disciplines varies, and the educators teaching in these programs often come from different backgrounds (Gonzalez & Kuenzi, 2012). These individuals work with STEM students on a daily basis and are influencers in their lives (Teven & Herring, 2005), ultimately impacting student career choice. Therefore, it must be asked, who are these educators, where do they come from, what training do they receive, and what are their perceptions of the students they teach?

STEM Students: Are They All the Same. In the last decade, studies focused on STEM students have been rather prolific. However, those studies focused on retention (Watkins & Mazur, 2013), recruitment (Yelamarthi & Mawasha, 2010), gender (Griffith, 2010; Marra et al., 2009), and race (Price, 2010). While research is commonplace in these areas, comparisons of students between majors within STEM are not as evident, especially in educator perspective and teaching styles best suited to each discipline. Thus, this study provides direction for filling the gap in the literature by asking those closest to STEM students their opinions on how their students learn and the similarities of students in different majors.

Teaching Methods – Differences and Similarities within STEM Subjects. Large-scale comparisons of STEM educators are not evident in the literature. Instead, findings suggest that each area of STEM becomes fiefdom like (Sanders, 2008), while others suggest that STEM education involves the intersection of more than one discipline (Corlu et al., 2014). None of this work has been corroborated by asking STEM educators their opinions or by directly comparing the disciplines. It is the purpose of this paper to begin the discussion regarding STEM educators and to encourage further comparisons and work to understand those that are influencing and teaching future STEM majors.

Cross Discipline Teaching in STEM Subjects. There is a belief by some STEM educators that teaching in cross-disciplinary subjects or departments will benefit other aspects of their teaching (Wang et al., 2011). Others believe that they need to teach multiple subjects to encourage students to integrate subjects into their problem-solving exercises (Hoachlander & Yanofsky, 2011). Still, others investigate educator interaction, knowledge gain through peer collaboration, and the increase in successful cross-disciplinary teaching within STEM and other fields (Fulton & Britton, 2011). This paper investigates what the educators believe in cross-disciplinary teaching and how that influences their students.

Skill Sets Required. Current STEM discipline classrooms, due to the cross-disciplinary environment, require STEM educators to be able to facilitate learning through classroom interaction rather than through the traditional lecture-style teaching model (Ejiwale, 2012). This new style of teaching calls for STEM educators to be trained, or at least proficient, in multiple areas (Bybee, 2013). This training provides the foundation necessary to teach in multiple STEM disciplines. Without this training, STEM educators may find themselves in situations where they experience symptoms of the imposter syndrome (Simmons, 2016), or for one reason or another find themselves unable to teach in a cross-disciplinary situation.

Types of Training Required and Provided. STEM educators in most K-12 classrooms are required by various state standards to have specific training (Goldhaber et al., 2015; Henry et al., 2014; Howell et al., 2016). These standards provide a uniform level of studies in education and dictate that as higher grades are taught/certified, more specific training in the topics to be taught is completed. Courses taught beyond the secondary level (college professors) require advanced degrees and experiences in the subject areas, although the level and type of training often varies according to the institution, region, and country (Marginson et al., 2013). While some suggest specific methods of training STEM educators, at this point there is little incentive to do so and limited follow up due to tried-and-true processes of training educators (Walz et al., 2016).

Thus, the questions about STEM educators and what they think about teaching their students are highly relevant. Their beliefs impact the teaching style they selected and how much preparation they seek to enhance their teaching and course preparation activities. As a precursor to further inquiry in this area, the researchers were compelled to learn more about the educators' thoughts on teaching methods for STEM majors and their ability and confidence when teaching across disciplines. All of these factors contribute to their motivation, and depth at which they pursue further education, and approach the students in the classroom.

As this topic has been developed and narrowed, the researchers wondered whom STEM educators are, their background (Lucietto & Russell, 2018), and how they teach. While interacting with STEM educators teaching in the different educational levels, the researchers realized that education, beliefs, and ages taught often did not appear to be correlated. The questions resulting from these inquiries and observations follow:

What do STEM educators think

- about the qualitative similarities and differences between teaching students in different STEM majors,
- and similarities and differences in teaching across STEM disciplines?

Methods

The survey used in this study was designed to explore the demographics, as well as some other areas that involved STEM educators. The intent of gathering this data is to learn more about their development of instructional strategies supported by their knowledge of their students and the subject matter they teach. The focus of this work is on the section of the survey concerning differences between students and differences in teaching STEM disciplines.

Survey development. An outline was created to develop the sections, assure that there was no overlap, and provide meaningful information to answer the research questions. Open-ended questions were directly asked to probe respondents for a more in-depth understanding than a generalized multiple-choice survey (Blair, Czaja, & Blair, 2013). While this is not generally a preferred method of surveying in the online environment, furthering our knowledge regarding research opportunities is best served with this approach (Van Selm & Jankowski, 2006).

Survey Questions. While the questions used in this survey are open-ended, the researchers intended to delve into areas they could not predict. This technique, while considered somewhat unorthodox, provides insight that may not previously have been available. As this is the first in what is anticipated to be a series of surveys and subsequent findings disseminations, open-ended questions provide the best guide to the future path of this research. The questions from the survey that are reviewed in this work follow:

- Q1-Do you believe that your students are the same as other STEM students?
  - Q2- Please explain why.
- Q3-Within STEM, do different teaching methods work for different majors?
  - Q4 -Explain your answer.
- Q5-If asked, do you believe you could teach in an other area?
- Q6-What other skill sets are required for those teaching other STEM majors?

Collection Methods. A variety of educator professional organizations, school districts, and individuals were contacted to distribute the survey over as wide an area as possible. These contacts were entered into a list, and any appropriate follow-up was noted. Participation in the survey was entirely voluntary. Distributions of the survey link were made to attempt to cover science, technology, engineering, and math educators in equal numbers by contacting organizations specific to each discipline.

Data Analysis Methodology. Responses to 32 questions, with the six listed above the focus of this article, were gathered using an online Qualtrics survey which was left open for five weeks. The survey received 211 "hits"; however, ten hits were blank, leaving 201 usable responses (Baruch & Holtom, 2008). Percentages in this document are based upon the 201 number unless otherwise noted. Using Microsoft Excel, each question was individually analyzed to reveal underlying trends in demographics and beliefs. Figures were prepared to illustrate the composition of the educators' responses further. The responses to free-answer questions were read, word frequency analysis was performed, and cluster analysis was completed on findings. These notes were summarized to reveal connections between questions and trends in beliefs and teaching practices. Particularly insightful quotes supporting the findings were included in this work.

Further analysis of the available data was done using NVivo software (NVivo, 2018), focusing on the development of themes and relationships within the data. Word frequency data, corresponding to the weighted percentage, was obtained for each of the survey questions and then was reviewed for similarities and relationships. The use of the data extracted using this method and the overall review of response composition was used to answer the research questions.

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Findings

The questions asked of the respondents fall into three different areas. They follow the concepts provided by the questions and intersect through the everyday use of words in the participants' answers. These categories are skills, teaching, and students. Figure 1 illustrates the level of usage of each word vis a vis the layered pyramids, while the boxes between the pyramids provide commonalities between those questions/focus areas.

Figure 1 is based on the word frequency data collected. Each of the three pyramids corresponds to one research question. The tip of each pyramid contains a word best representing the question. The five lower levels of each pyramid contain words that frequently occurred, by weighted percentage, with the more frequent words appearing nearer the tip of the pyramid.

The word "knowledge" is pervasive throughout the responses and this is reflected in the thematic intersections shown in Figure 1. Skills and teaching are shown at the top of the graphic due to the higher level of commonly used words. In addition to the word "knowledge," words such as content, students, communicate, subject, change, and teaching are used at higher levels than other descriptive words. This analysis provides the distinct impression that the respondents felt strongly about this intersection of teaching and skills, reinforced through the use of words such as content, communicate, and change.

Considering the demographics of the desired participants, STEM Educators emphasized content as discipline specific. Further, they noted that the skill set available to teach the various STEM subjects is as important as the content itself and the ability to communicate these concepts to the students. Considering the intersection of teaching and students, the respondents shared the need to teach actively and be open to different ways of connecting with the students. Further, they felt that most students did not respond to abstract concepts and that the act of teaching students and encouraging them to learn sometimes required different techniques. All of this was shown in the relative use of common words. Finally, the respondents indicated that it took more skill to change the way they encourage students to learn and apply what they learn in school and beyond.

Considering the Research Questions. By further review of the data as presented in the pyramids in Figure 1, many things are noted when considering the participants' thoughts regarding their students as well as other STEM students. Foremost, they acknowledge that STEM students are different. They also discuss community and knowledge, suggesting that students are different based on their demographics, and preparation for STEM careers.

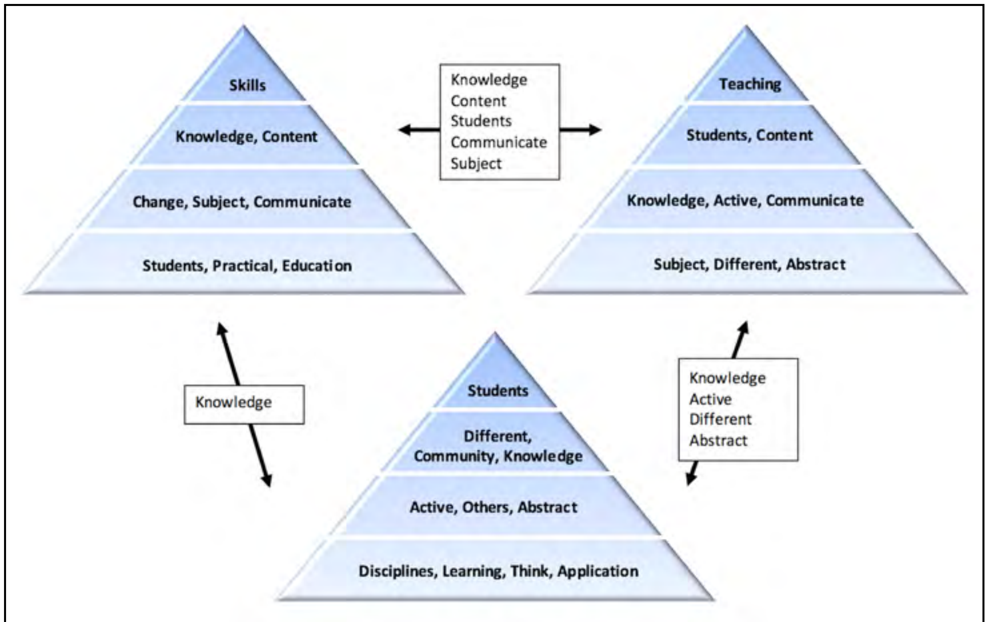

Figure 1. Intersection of Themes and Commonalities

As the data is probed, a sense that active learning that focuses on applying theory to real life problems and scenarios is best suited to the STEM student. Finally, further probing provides a better understanding that issues are different in the various STEM disciplines, how these students learn STEM subjects vary, and much of that is based upon how they think and apply what they learned.

The second question regarding teaching also provides an abundant amount of data which initially provided a strong foundation that students are the focus while content is also of great importance. Further knowledge of teaching, while working in an active learning environment, and effective communication are critical in teaching STEM subjects. While similarities or differences were not as defined as the researchers would desire, it is evident that STEM educators responding to the survey believe the students are as different as the subjects they are taught.

Review of the Phrases and Supporting Statements. When considering the different students, there is also an emphasis on the differences between Engineering/Technology students and the others: "Engineering students are more interested in designing solutions to problems. They like putting the math and science to practical use." Another educator writes, "Typical IT students want more hands-on approach than a typical engineering student." Others mention how their institutions have just begun emphasizing STEM, so their students are less prepared: "Our district is just starting to put more emphasis in these areas. Our students have less exposure to these practices at younger ages."

One educator alluded to the fact that this may be a more complicated question than yes or no: "It depends. All college-age students share characteristics. Some colleges have higher-rated students. Differences in learning styles do exist between majors, but students of all learning styles will be found in all majors".

Researchers were able to infer that STEM educators believe that a rough continuum exists in how much "hands-on" and "theory" is emphasized in STEM disciplines. The researchers wish to note that this continuum was roughly determined from the surveyed educators and requires more analysis. Figure 2 presents this continuum.

Some educators had especially insightful thoughts on this question. One wrote, "I don't believe any student is different and they all have the potential to do great things with STEM. Diversity of opinion and ways of thinking about STEM are crucial to progress." Another wrote, "No one is identical, but everyone has the same capability, regardless of high school grades, university, race, creed, sex, or any other cultural identifier. Every single one of us is resilient, curious, creative and whole." A different thought: "Everyone is different. Everyone has their own motivations, strengths, and weaknesses."

Teaching Methodology, Skill Sets, and Ability to Teach in Different STEM Disciplines. The intersection of teaching methodology, skill sets, and ability to teach across STEM disciplines is essential to understand. The three areas are directly related. The competent educator must have a technical understanding of the material presented- whether it be math, science, technology, or engi-

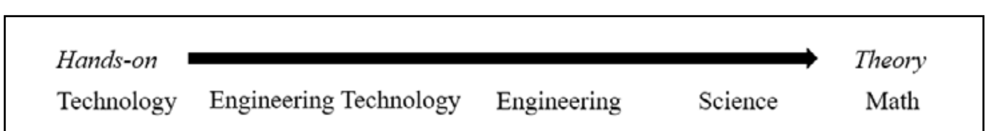

Figure 2. Hands-on and Theory Continuum

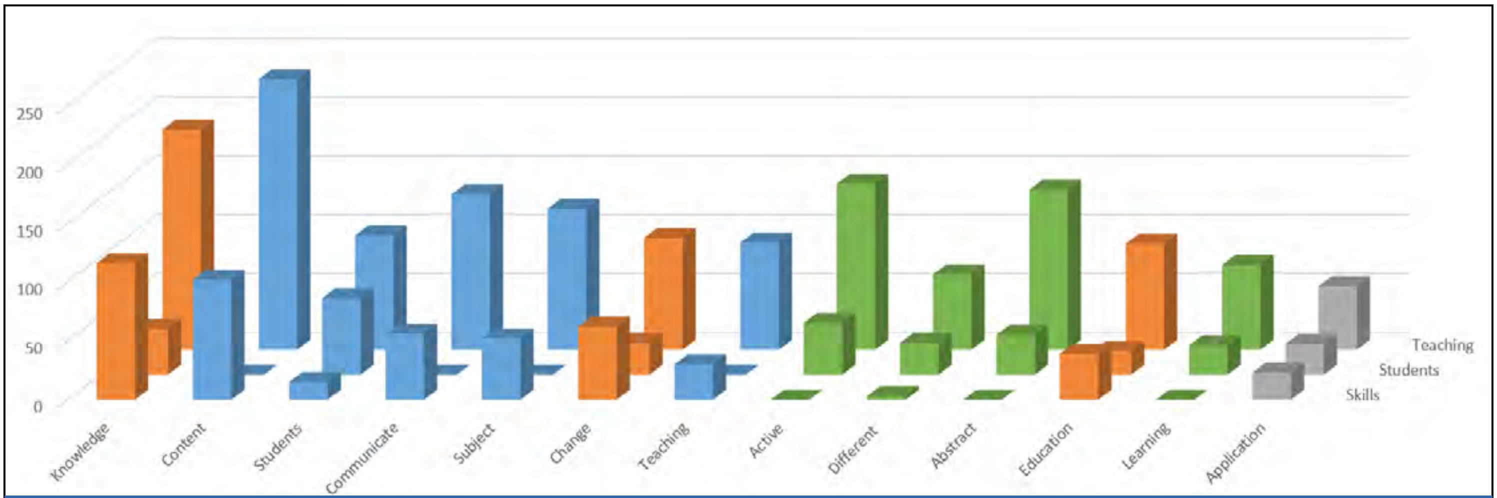

Figure 3. Word Frequency Weighted Averages: Skills, Students, Teaching

neering. Directly related to this, the teaching methodology used to present the subject may differ based on the content presented. The authors suggest that an educator must have an understanding of the different STEM majors they are teaching to adapt their teaching methodology. Thus, in general, to teach across STEM disciplines, an educator must have an understanding of both the subject matter and the ability to present this subject in a way that matches the learning expectations of the student audience.

Further consideration of words used throughout the responses to the survey questions yielded Figure 3. This provides a weighted percentage of usage of words common to two or more questions, considering the emergent themes of educator skills, students, and teaching. The words appearing most often are shown on the longer axis.

Teaching Methodology. Educators were asked if they believed that different teaching methods were more appropriate for different majors. About fifty-percent of educators agreed, while about 8.96% indicated disagreement. However, 40% did not respond, possibly due to the length of the survey. Educators were asked to explain the reason for their choice.

The researchers noticed a slight contradiction among some educators' responses. When asked to explain their reasoning for indicating that differences are present, some educators offered general teaching methods for all majors. They write "All require a mix of theory and hands-on application" or "almost anything can be related – or should be related to a practical, real-life application."

The educators responding that there were no differences in this category generally emphasize broader teaching strategies: "If something is truly STEM, the approach applies to it." Another theme among these educators is that teaching "depends more so on how students learn" and "depends more on the cohort of students than the major."

One educator summarized the findings by saying: "No matter what you[r] major, we all do learn best through experience the material vs. it being told to us. It is how we learn as babies, and it is the most natural way to learn, at least if your goal is retaining the material beyond exam day!"

Ability to teach in Different STEM Disciplines. Educators were asked to indicate whether they would be able to teach in a STEM area other than their own. The results showed that 33.81% of STEM educators believed they could teach in another discipline while 2.49% said "no" and 31.84% said "maybe." About 27.36% did not respond.

Skill Set in Different Disciplines. Educators were asked what skills are necessary to teach in a STEM area. The most common answers were "Knowledge of the subject" and the "Ability to apply a variety of teaching styles." One educator lists the most common ideas: "Knowledge of teaching techniques, knowledge of the subject, and passion for education." One mentions the importance of "[l]ifelong learning."

Many educators state that "all faculty need hands-on industrial experience, in addition to their formal education" and a need for "[a]n understanding of how the subject is used in real life." Others emphasize the need for the educator to "[h]ave a clear idea of what are the student motivations to pursue a specific major" and "an understanding of what students want to learn and what drives them to help them become what they want." Another group of educators list basic skills that apply to a variety of careers. A few examples are "[f]lexibility; open-minded; ability to lead and control discussion"; and "[t]eam oriented, sharing resources, patience.".

Some educators had especially insightful statements. One expresses the need for "[c]omfort with ambiguity, acceptance that you don't know everything, [and] learning to be a coach vs. a lecturer."

Smaller groups of educators don't express a need for extra skills. They write, "teaching skills are teaching skills. It should not matter" and "pedagogical skills can be transferred across each discipline."

Discussion

Earlier work shows that STEM educators responding to the survey were most often male, in their mid-50s, and generally teaching in engineering technology programs. Most likely this is the case because the survey was distributed through engineering technology distribution lists and throughout STEM educators in K-12 during the summer when these educators are not working. Further distribution of a refined survey instrument focused on areas lacking in-depth research may be the subject of future work.

Further limitations may be due to the open-ended questions. These questions, as described earlier, were developed intentionally to delve into areas that the researchers may not have identified as potential areas of future research. They also found that some of the questions did not provide options suitable to K-12 educators, which would be remedied in future work on this project.

When educators were asked if their students were the same as other STEM students, nearly half believed that they were not the same. Many of these educators cited the inherent differences students display as individuals as their reasoning, with Figure 1 backing up this trend. Understanding the differences in students likely affects how these educators select teaching methods, as they recognize that different students respond better to specific methods.

Based upon results of the survey, the researchers developed a concept they call the "Hands-On and Theory Continuum." This concept graphically shows how the various STEM disciplines relate to one another by the relative use of hands-on application and theory, as determined by educators' responses to various survey questions. The concept includes determinations made from questions featured in previous work (Lucietto & Russell, 2018). This figure reflects the results of the word frequency analysis in that STEM educators perceive differences between students in different disciplines, thus influencing how they are taught. The continuum is shown in Figure 2.

Respondents focus on the differences between the individual rather than grouping them by major. There was a strong theme among these educators that their students were unique as individuals, but that ability exists for all students to be successful in pursuing STEM careers. When asked about teaching different majors similarly or differently, of the responding educators, nearly 50% indicated that it was necessary to teach each STEM field differently, backing up the differences indicated in Figure 2. Only 34% of the STEM educators felt they could teach another discipline, while 2.5% said they could not, with the balance either saying maybe or were non-responsive. This may be related to the training these educators receive, as STEM-specific training exists but is not widely implemented (Walz et al., 2016).

In teaching STEM, the educators noted that a technical understanding of the subject is necessary. Further, when teaching across disciplines, those responding educators believed that an ability to apply various teaching methods is vital. When asked to indicate the skills necessary to teach STEM, respondents indicated a need for the educator to know their subject well and to be able to apply a variety of other teaching techniques, correlating with the idea that differences in students necessitate the use of various teaching methods. Some indicated necessary professional skills like patience and teamwork. The final group indicated that no unique skills were required to teach STEM beyond necessary teaching skills. Educators appear to be able to generalize what skills are necessary for teaching STEM but are not confident in transferring these skills to a discipline other than their own. Improvements in training may increase educators' confidence.

Conclusion

Results show that STEM educators are split between feeling their students are different individuals and sharing their similarities. STEM educators differ in their confidence in teaching in a different discipline than their own, as only about a third of educators say they were able to switch. Another third indicate an interest in trying by saying they might be able to switch disciplines. The lack of complete confidence provides an understanding that while educators are trained in their discipline, they are not comfortable teaching other STEM disciplines.

Survey responses underwent content analysis using word frequency analysis, revealing connections between responses and supporting increased understanding of STEM educators. This provided evidence that STEM educators think that content is discipline specific, but that teaching methods are transferable. Some educators believed that no special skills are required to teach STEM while others stressed that professional skills are paramount to success in the classroom. While educators seem to understand the skills required to teach in their STEM discipline, only a third of educators are confident in their skills to teach across disciplines (34%). This discrepancy may stem from a lack of understanding of the content. While educators recognize that there are differences between students in different STEM disciplines, they may not feel that they understand the differences enough to be confident teaching a different group.

When thinking about their students, STEM educators stressed the uniqueness of their students as individuals but believed that all students possess similarities in their interests in STEM, their drive, and their inherent ability to succeed. Many educators also believed that a keen understanding of these individuals is necessary to teach STEM. Based on this information, educators responding believe that commonality exists between STEM students and across disciplines but that each discipline and student possess uniqueness leading to challenges in teaching across these lines.

For future iterations of the survey, focus needs to be given to developing questions that are both clear and concise. The length of this survey prevented the researchers from gathering sufficient information from specific questions, as the researchers noticed falling percentages of question completion towards the end of the survey.

When the STEM educators responded to the question regarding the idea if their students are the same as other STEM students, respondents tended to believe their students were different. When asked to explain, they noted the idea that students are unique because they are individuals. They then were asked to indicate if different teaching methods work in different STEM fields, and the tendency was for educators to agree with the statement. Finally, when asked about skill sets, the educators fall into three categories: those who believe no special skills are required to teach STEM, those who believe professional skills are required, and those who believe extensive knowledge of the subject is imperative.

The researchers compiled survey results and developed the Hands-on and Theory Continuum (Figure 2). This figure shows that differences exist between STEM disciplines, though they are typically grouped under one umbrella. STEM educators recognize these differences, as they work with students and this content daily, indicating that grouping many disciplines as STEM may not be ideal. The educators surveyed were able to list skills necessary for teaching STEM, though these skills were mostly those needed for teaching in general. This suggests that the community should focus on aiding educators in developing a foundation of teaching methodology that is applicable across all STEM disciplines, with specialization for each discipline based on the differences laid out in Figure 2. This may increase educator confidence, causing a more significant percentage of educators to teach across disciplines, aiding in solving educator shortages in specific disciplines.

This and previous work provides insight into the population of STEM educators, who they are, their thoughts regarding teaching, and their thoughts about their students. The intersection of teaching methodology, skill sets, and teaching across disciplines was explored in this paper. It was determined that confidence in teaching across disciplines relates to the educator's technical skill in those areas and an understanding of a need to adapt teaching methodology. The responses guide researchers in areas to focus on for future research and surveys.

Future Work. To further our understanding of this population of educators, additional studies focused on the population at large are necessary. While analyzing the data, researchers also found areas where the survey should be improved. It is anticipated that a project designed to survey a larger population, support interviews, and more in-depth probing of STEM educators will result in significant findings. Additional work in this area is planned, and funding will be sought.

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Dr. Anne Lucietto is an Assistant Professor at Purdue University, Purdue Polytechnic Institute, School of Engineering Technology. Her research focuses on STEM students, often more specifically engineering technology students. Her desire to learn more about the students, those that teach them and supporting students as the learn how to write and interact with technology will encourage more students to pursue STEM degrees and strengthen the technical pipeline.

Liza Russell is a recent graduate of Mechanical Engineering at Purdue University. She began this work under Dr. Lucietto in the summer of 2017 as a part of Purdue's Summer Stay Scholars program and continued researching through her years at Purdue. She has performed research on STEM students as well, with a special focus on Engineering Technology students and graduates. She will soon enter industry, working as an Associate Product Engineer at Allison Transmission.

Emily Schott is a recent graduate of Purdue University with a BS in Aeronautical and Astronautical Engineering. She was introduced to undergraduate research during the summer of 2018 while participating in Purdue's Summer Stay Scholar program. She has helped with several of Dr Lucietto's other projects and has designed part of the supporting architecture for an Earth-Mars cycler system as part of her senior design course. Emily will soon be starting a position as a Systems Analyst with In-Depth Engineering.