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Seeds of STEM: Developing Early Engineering Curriculum

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Seeds of STEM: Developing Early Engineering Curriculum

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Abstract

Myriad studies have shown preschool to be an integral factor in development and learning for young children (Ackerman & Barnett, 2005; Barnett, 2011). Children have the opportunity to be engaged in age-appropriate activities and begin understanding the world they live in. This highly-developmental time during the life span is therefore the perfect time to introduce concepts in the Science, Technology, Engineering, and Math field, specifically engineering. This project aimed to create an engineering curriculum for preschool students that was both developmentally and culturally appropriate, and a professional development series to help teachers feel more confident with STEM education. Through the collaboration of engineers, preschool teachers, education researchers, and psychologists, this project demonstrated preliminary success and has the potential to change STEM education interventions.

Seeds of STEM: Developing Early Engineering Curriculum

Myriad studies have shown preschool to be an integral factor in development and learning for young children (Ackerman & Barnett, 2005; Barnett, 2011; Burgess, Lundgren, Lloyd, & Pianta, 2001; Consortium for Longitudinal Studies, 1983; Reynolds, Temple, Robertson & Mann, 2001). Preschool has profound effects on children's literacy, comprehension, and reasoning (Ackerman & Barnett, 2005; Burgess et al., 2001; Brenneman, Stevenson-Boyd, & Frede, 2009). Children have the opportunity to be engaged in age-appropriate activities and begin understanding the world they live in. This highly-developmental time during the life span is therefore the perfect time to introduce concepts in the Science, Technology, Engineering, and Math (STEM) field. Early education in engineering in particular is an important development in upcoming curriculum because of the potential it has for student success. The purpose of this paper is to demonstrate the need for a preschool engineering curriculum. This paper reviews literature to support why preschool is the crucial age, reasons engineering is the missing subject from the curriculum, and a strategically designed method of using preschool teachers to develop the curriculum with the aid of key professional development training.

Children naturally explore and question the mathematical and scientific world around them (Bowman, Donovan & Burns, 2001; Brenneman et al., 2009; French, 2004; Gelman, 1999; Karmiloff-Smith, 1988; Worth, 2010). By providing developmentally appropriate knowledge and concepts, early childhood education has an opportunity to grow that inherent enthusiasm towards learning, which "contributes to future success in and out of the classroom" (Brenneman et al., 2009). Furthermore, language and vocabulary are reinforced by integrating STEM concepts into the classroom as students learn new words, ideas, and communications (Brenneman et al., 2009).

This enthusiasm and holistic growth in education has the potential to inspire future engineers starting at a young age. Engineering in general is a vital part of our globalized economy and workforce. The United States is continually falling behind in this regard as more and more students stray away from following an engineering program in their undergraduate and graduate careers, especially women and minority students (Custer & Daugherty, 2009; Jenniches & Didion, 2009; Katehi, Pearson, & Feder, 2009; Schunn, 2009). Introducing STEM, and specifically engineering, concepts early can engage students early on, providing them with a more well-rounded foundation to pursue their collegiate studies. The importance of preschool education, children's inherent interest in how the world works, and the necessity for future engineers demonstrate the importance of developing and implementing an engineering curriculum that could be integrated into every early education classroom (Brenneman et al., 2009; Burgess, Lundgren, Lloyd, & Pianta, 2001; Chen & McCray, 2013).

Cunningham (2009) describes children as "born engineers". They reason, manipulate, and observe the way mathematical and scientific concepts occur. By incorporating engineering concepts into early education curriculum, children are provided developmentally appropriate knowledge and skills to further examine the world and grow their interest in science, technology, engineering, and math (Ackerman & Barnett, 2005; Brenneman et al., 2009). Science, technology, and math are mostly covered in typical preschool curriculum (Bagiati & Evangelou, 2015). Integrating engineering gives children the opportunity to examine these concepts and build upon them in a new way (Bagiati & Evangelou, 2015).

This natural-born tendency for children to explore the world around them, and early exposure to engineering topics and application of science, math, and technology has the ability to debunk stereotypes and change attitudes and beliefs toward the field (Brophy, Klein, Portsmore,

& Rogers, 2008). Social learning theory, proposed by Albert Bandura (1977), demonstrates that people learn from social models that influence their attitudes, beliefs, and perceptions of self-efficacy (Plant, Baylor, Doerr, & Rosenberg-Kima, 2009). Incorporating engineering curriculum and academic support in the classroom therefore has the potential to affect students early on. Camilli, Vargas, Ryan, and Barnett (2010) explain that educational and other intervention programs produce “positive and long-term effects for programmatic interventions on cognitive and social-emotional outcomes”. Without such educational and social interventions regarding engineering and STEM, the field will continue to fall into stereotypical patterns. For instance, Jenniches and Didion (2009) state that young women do not enter the engineering fields because of early emphasized stereotypes that girls cannot do and are not interested in STEM, and that all engineering fields are “male-dominated” and unwelcoming to women. Similarly, Katehi and colleagues (2009) explain that current engineering curriculum excludes women and minorities because it is centered on attracting a specific, stereotypical group of people. There is little effort in making curriculum interesting, and more importantly relatable, to all genders, ethnicities, cultures, and abilities (Katehi et al., 2009). Early exposure, therefore, has the potential to change students’ attitudes toward STEM and engineering, and affect their cognitive, social, and emotional beliefs about their success in engineering.

Although engineering education has the potential to fit seamlessly into preschool classrooms, there are challenges to be expected in developing such programs. Incorporating engineering into preschool classrooms is no easy feat and will require the collaboration of teachers, administrators, and curriculum developers. Creating a curriculum that is developmentally appropriate and well-rounded will require the understanding of preschool learning capacities and ability to integrate engineering concepts into those capacities. In addition, effective curriculum needs to be supported by teachers that feel confident and prepared to teach those subjects.

Developing a curriculum that is both developmentally appropriate and holistic requires time, energy, collaboration, and a deeper knowledge of the subject. Children have the capacity to understand and participate in critical thinking and abstract reasoning (Brenneman et al., 2009). Curriculum, instead of simplifying engineering information, should intellectually challenge students and grow their capacities to explore, comprehend, and reason with their world (Evangelou, 2010; Katz, 2010; Van Meeteren & Zan, 2010).

In order to effectively challenge and engage preschool children, educators need to have a base knowledge of STEM and engineering. A common conception is that preschool and early education teachers are not prepared or confident in their abilities to teach STEM, especially engineering. Early education teachers are generally not specially trained in these areas, although Chen and McCray (2013) explain that most teachers do feel comfortable and confident in teaching math and science, even if they are not necessarily confident in their own abilities. Because teacher preparedness and efficacy are crucial elements of a successful classroom, ensuring teachers feel confident and wholly able to complete engineering tasks and explain concepts is another realm in which to develop an early education engineering curriculum. In order to succeed at developing and implementing this program, it is necessary to approach these challenges as opportunities for growth and expansion. Through discussion, literature review, and collaboration, we can create a high-quality program that not only engages early learners, but improves teacher knowledge, understanding, and confidence in engineering.

To properly develop a curriculum that can be fully understood by preschool aged children and still holistically cover the engineering design process and engineering related material, it needs to fit with three to five year old developmental capacity. Incorporating engineering information into play and hands-on instruction allows children to comprehend the material in the same way they begin to comprehend the world around them (Kinzie, Pianta, Kilday, McGuire, & Pinkham, 2009). Chien and colleagues (2010) explain that there are different models of classroom engagement that all result in a variety of learning outcomes, including free play, teacher instruction, and scaffolding. By identifying how teachers engage students and what processes work best in the classroom, curriculum developers can engage students in engineering concepts and the engineering design process.

Furthermore, developing effective professional development for teachers is another vital component of the project that will hopefully contribute to its success. Ackerman and Barnett (2005) explain that “one of the most crucial variables leading to high-quality preschool is teacher education and training”. Professional development, in general, needs to focus on teacher needs, specifically where they believe they need the most assistance (Chen & McCray, 2013; Roehrig, Dubosarsky, Mason, Carlson & Murphy, 2011). For engineering curriculum, we need to focus on those needs in an engineering context. What tools or resources can we provide to teachers to make them feel confident in their abilities and understanding of engineering and engineering related concepts? Student learning and success is influenced greatly by the adequacy and strength of a teacher’s knowledge, therefore professional development needs to be a crucial part of the curriculum (Ackerman & Barnett, 2005; Chen & McCray, 2013; *Learning about Teaching*, 2009). Providing teachers with the potential and opportunity to strengthen and improve their skills will hopefully result in greater confidence in engineering teaching and further help eliminate stereotypes and stigmas associated with engineering and STEM (Brenneman et al., 2009; Cunningham, 2009; Custer & Daugherty, 2009).

Overall, the need for an early education engineering curriculum is supported by the inherent ability of young children to engage in engineering tasks and general importance of engineering in early childhood, the importance of preschool education, and the need for future engineers in a continuously growing global society. Although there are challenges to creating such a program, these challenges can be viewed as opportunities for expansion, growth, and further understanding of the implications of this project. By incorporating how children already learn and engage in the classroom, we can understand in what way we can integrate engineering concepts. Furthermore, with effective professional development, we can provide teachers with the resources they need to understand new engineering material, and feel confident in their abilities to apply and teach that material. Engineering is a vital component of our society that continues to expand and stretch into all aspects of our world. It is our goal to engage the younger generation in this field, and help produce the world's future engineers.

As demonstrated in the original proposal, *Seeds of STEM* aims to develop a curriculum with the collaboration of STEM education professionals, preschool teachers, psychologists, engineers, and students. This intervention curriculum will be focused on STEM practices aligned with the new set of national standards, building on the findings that young children actively form theories about the world and are capable of abstract reasoning, STEM skills are teachable but rarely taught in pre-kindergarten, and the acquisition of these skills supports overall academic growth and improves school readiness. *Seeds of STEM* aims to support the teaching and learning of STEM practices in early childhood, and as a result increase student STEM readiness. Specifically, this goal will be achieved through a partnership with Head Start teachers to develop the *Seeds of STEM* curriculum.

There are several objectives throughout the project that will help the researchers identify professional development and curriculum needs, establish successful programs, and reliably test those programs. The first objective is the in Preschool Teacher Survey which acts as a baseline measure for STEM instruction in the classroom and teacher self-efficacy regarding STEM. Utilizing several instruments, teachers provide insightful information that will be the initial starting point for the following professional developments and curriculum. The second objective is Professional Development, and the successful planning and implementation of those sessions. Descriptions of and feedback from these sessions will be analyzed to improve professional development once the project reaches the pilot stage in a new preschool. The final objective is to develop a Curriculum that is suitable, engaging, and interesting for early childhood students. These objectives serve to answer several research questions, mainly: 1) what needs, practices, and experiences do preschool teachers have and how does this inform the professional development they need? 2) what are the strategies to develop successful PD in needed content, and how successful is each session in achieving desired goals? 3) What are the strategies to develop a successful curriculum and how does a successful unit look? Several units come together to create a comprehensive curriculum that introduces the engineering design process and emphasizes each specific step. Overall, this project aims to successfully create and implement an engineering curriculum for preschool students, as demonstrated in the objectives and research questions described below.

Objective 1: Preschool Teacher Survey

The initial teacher survey was administered to determine baseline information regarding teacher experience, practices, and needs, specifically in STEM and engineering. Data collected was also to be used for planning and implementing specific lessons within the professional development to help teachers feel comfortable and confident in the engineering curriculum. Each part of the survey addressed a specific need of the grant team, including areas of pre-existing engineering knowledge, confidence and efficacy in teaching engineering, and demographic and educational background. All teacher survey materials are included in Appendix IA.

Method

Participants

A total of 67 Worcester Head Start Teachers and Assistant Teachers were recruited. Sixty-four completed the survey (61 female and 3 who did not report) on November 23 and 24, 2015. Of those teachers, 33 were Head Teachers and 31 were Assistant Teachers. Seven teachers volunteered and were accepted as teacher developers prior to the survey based on four criteria (length of stay in the program, CLASS scores, recommendation, and educational status). Originally eight teachers volunteered and responded to the survey as such, but only seven committed after the initial survey. These teachers built the curriculum and professional development alongside the grant team.

Measures

An online survey was administered during the introduction meeting with the grant team. The purpose of the online survey was to obtain baseline measures for the study. The researchers utilized previously created instruments, as well as self-made instruments, to gather baseline data on teachers' self-perceived STEM abilities and attitudes, desires for professional development regarding STEM education, openness and willingness to work with students from all backgrounds and histories, and basic demographic and teaching history information.

The online survey consisted of seven instruments including STEM Instruction, STEM Engagement in the Classroom, STEM Teaching Outcome Expectancy Beliefs, Personal Engineering Teaching Efficacy and Beliefs, Teacher Multicultural Attitude Survey, Perceived Professional Development Needs, and Educational History.

STEM Instruction. This measure was adapted from The Golden LEAF STEM Initiative Evaluation with the purpose of helping the researchers understand teachers' already existing STEM practices (Faber, et al., 2013). The instrument asked teachers to rate how often their students engage in specific tasks on a 5 point Likert scale (1-Never to 5-Very Often) that are indicators of STEM education. For example, some items included in the instrument were "Develop problem solving skills through investigation" and "Recognize patterns in data."

STEM Engagement in the Classroom. In order to further detail tasks used within the classroom, the teachers additionally answered questions about how frequently preschool children engaged in different engineering-related tasks. The frequency of these tasks could be rated on a 5 point Likert Scale (1-Never, 5-Very Often). Items included "Ask questions about things in the natural world that they see around them", "Change explanations based on new information", and "Brainstorm possible solutions to a problem", among others.

STEM Teaching Outcome Expectancy Beliefs (STOES). This instrument, adapted from the Golden LEAF STEM Initiative Evaluation (Faber et al., 2013), asked teachers to rate how influential they perceive teacher effort to be on student success, specifically in STEM education. This instrument was presented on a 5 point Likert scale (1-Strongly Disagree to 5- Strongly Agree) and included items such as, "When a student does better than usual in STEM, it is often because the teacher exerted a little extra effort" and "The teacher is generally responsible for students' learning in STEM". STOES was originally focused on science and technology education, but was adapted to encompass all of STEM.

Personal Engineering Teaching Efficacy and Beliefs (PETEBS). All teachers saw the same questions regarding confidence in understanding and effectively teaching or explaining engineering concepts. Items such as "I know the steps necessary to teach engineering effectively" and "I know what to do to increase student interest in engineering" were measured on a 5 point Likert scale (1-Strong Disagree to 5- Strong Agree). If teachers indicated in a separate question they currently or previously had taught engineering to preschool children, they were also provided supplemental questions which were also adapted from the PETEBS. This section of the PETEBS included items such as "I am continually improving my engineering teaching practice" and "When teaching engineering, I am confident enough to welcome student questions" and were also measured on a 5 point Likert scale (1- Strongly Disagree to 5- Strongly Agree).

Teacher Multicultural Attitude Survey (TMAS). Furthermore, the researchers hoped to gauge attitudes towards students of multicultural backgrounds in order to understand how educators view success outcomes, culture, and STEM. The instrument asked them to rate different responsibilities and attitudes of educators in the classroom on a 5 point Likert scale (1-Strongly Disagree to 5-Strongly Agree). Questions included items such as "I find the idea of teaching a culturally diverse group rewarding", "Teachers have the responsibility to be aware of their students' cultural backgrounds", and "I can learn a great deal from students with culturally different backgrounds".

Perceived Professional Development Needs. Each question could be rated from "Not a Priority", due to either lack of interest or qualification, to "Essential". Items included concepts such as classroom management, how to plan engineering lessons for preschool children, background knowledge on engineering, and how to communicate with families about engineering education within the classroom.

Educational History. Educators were asked to provide information regarding previous grades taught, certifications, and years of experience. Demographic information, including languages spoken, age, and race/ethnicity was collected last in order to prevent participant bias.

Procedure

The initial Teacher Survey was administered during two information sessions on November 23 and 24. Each day, the grant team met with the groups for one and a half hours. The first day was mostly teachers, whereas the second day was mostly teacher assistants. First, the research team administered the informed consent sheet and compensation information. During the first information session, the compensation sheet and informed consent sheet were administered simultaneously. This process was different the second day, when the grant team administered the compensation sheet first, explained it, and then provided teachers and assistant teachers with the informed consent sheet. In the meetings, the first 45 minutes introduced the study to the teachers, explaining the key concepts and timelines, and the remaining time was used to administer the survey. All surveys were taken in the online format on the first day. On the second day, due to some technical difficulties, eight teachers completed the survey via pen and paper, while the rest completed the online version. Hard copy data was then entered and combined with the online data pulled from Qualtrics. Teachers and assistant teachers were then asked to fill out a brief survey about their feelings regarding the session. These surveys asked teachers and assistant teachers to indicate how much the session had helped them and to identify any areas of the project they were still unsure about.

Results

Teacher Characteristics. Age was presented in ranges from 18 years old to 64 years old. Seven teachers indicated their age between 18-24 years old. Nineteen indicated 25-34 years old. Thirteen indicated 35-44 years old. Seventeen indicated 45-54 years old. And seven indicated 55-64 years old. One person chose not to respond. The mean category was 35-44 years old. The majority of teachers were White (n = 48). They reported working with preschool children ages 3-5 years-old most frequently. Almost 50% also indicated they had been teaching for over 10 years. Specifically looking at the participants who indicated they were teacher developers, all 8 designated they had worked with 3-5 year-olds. Two mentioned they had worked in Grade 1, and two mentioned they had worked in middle or high school previously. The teacher developers had a mean of 5.5 when indicating how many years they had taught, which would be roughly between 5 and 10 years, on average. Similarly, the teacher developers had a mean of 5.0 when asked to indicate number of years having taught pre-school, which would be roughly between 5 and 10 years, on average.

STEM Instruction. Teachers and assistant teachers reported on the frequency of activities they engaged in with preschool children in their classroom. Table 13 (Appendix IIA) demonstrates the percentage of teachers who answered “Often” or “Very Often” to the items listed in the STEM Instruction instrument. Overall, without any implementation of Seeds of STEM, 95% of participants indicated they often, or very often encouraged their students to work in small groups. Other frequent instructional activities were developing problem-solving skills and engaging in conversations focused on lesson content. Each item was rated on a scale from 1

(Never) to 5(Very Often), and the overall mean for the instrument was 3.70. Cronbach's Alpha was 0.91. Within this instrument, the most percentage of teachers, 91%, indicated they encouraged their students to work in small groups. The lowest scoring item, with only 20% of participants indicating "Often" or "Very Often" was critiquing the way in which another person arrived at a judgment about something. A t-test measuring the mean differences between teachers that believed they had taught STEM to preschool students previously and those that had not or were unsure demonstrated no statistical significance.

STEM Engagement in the Classroom. Teachers and assistant teachers were asked to report on how frequently they encouraged certain STEM-related behaviors in the classroom. Table 14 (Appendix IIA) demonstrates the percentage of teachers that answered "Often" or "Very Often" to each item in the instrument. Out of all the items, 95% of teachers reported they often or very often encouraged children to ask questions about things in the natural world they see around them, a vital component to the engineering design process. Other highly encouraged tasks were developing explanations to phenomenon, changing explanations based on new information, applying past experiences, and describing real work problems. The overall mean for the instrument, measured from 1(Never) to 5(Very Often) was 3.87. Cronbach's Alpha was 0.94. The majority of participants (95%) responded often or very often to asking questions in the natural world, compared to only 53% who said they used models to test explanations. A t-test measuring the mean differences between teachers that believed they had taught STEM previously and those that had not or were unsure demonstrated no statistical significance.

STEM Teaching Outcome Expectancy Beliefs. Teachers and assistant teachers were asked to report on their outcome expectancy beliefs regarding teaching, specifically improving a student's STEM ability. The questions were rated on a Likert scale, 1 (Strongly Disagree) to 5

(Strongly Agree). Table 15 (Appenddix IIA) demonstrates the percentage of teachers who answered "Agree" or "Strongly Agree" to each item in the instrument. The overall mean for the instrument was 3.44. Cronbach's Alpha was 0.81. Of all the participants, 84% believed inadequacy of STEM background can be overcome by good teaching, which had the highest number of teachers agree or strongly agree. Only 24% agreed with the statement that ineffective STEM teaching can be blamed for students whose learning outcomes are less than expected. A t-test measuring the mean differences between teachers that had taught engineering previously and those that had not or were unsure produce statistically significant results, $t(62)=2.40$, $p=0.02$.

Personal Engineering Teaching Efficacy and Beliefs. This instrument was divided into two sections, depending on each teacher's response to the preceding question, "Do you currently teach, or have you ever taught, engineering to pre-K children?" The first four questions were only answered by those teachers who answered "Yes" to this question. If they answered "No", they were directed to the remaining 7 questions of the instrument.

Part 1. Thirty-four teachers answered yes to the previous question and were given four questions from the original PETEBS instrument. These questions were considered separately from the rest of the instrument because they indicated having some kind of engineering education background. Table 16 (Appendix IIA) demonstrates the percentage of participants that answered "Agree" or "Strongly Agree" to each item. The overall mean for Part 1 of the instrument was 3.59. Cronbach's alpha was 0.601. Teachers most agreed with the first item, "I am continually improving my engineering teaching practice", as 82% indicated they agreed or strongly agreed. Only 38% agreed they had the confidence to help a child understand an engineering concept he/she was having difficulty understanding.

Part 2. The rest of the PETEBS instrument was completed by all participants, regardless of their answer to whether or not they had taught engineering to preschool children before. Table 17 (Appendix IIA) demonstrates the percentage of teachers that indicated “Agree” or “Strongly Agree” to each item in the instrument. The overall mean for Part 2 of this instrument was 3.06. Cronbach’s alpha was 0.81. Forty-eight percent of teachers agreed or strongly agreed with the statement that they wondered if they had the necessary skills to teach engineering. A t-test measuring the mean differences between teachers who answered part one and those who did not had no statistically significant results.

Teacher Multicultural Attitude Survey. Participants were questioned about their attitudes toward multicultural differences in classrooms and students. They were given 20 items to rate on a Likert Scale from 1 (Strongly Disagree) to 5 (Strongly Agree). Several items were reverse scored. The overall mean for the instrument was 3.99. Cronbach’s alpha was 0.82. Table 18 (Appendix IIA) demonstrates the percentage of teachers that agreed or strongly agreed with each item in the instrument. Ninety-four percent of participants stated they found teaching in a multicultural classroom rewarding. Similarly, 95% of teachers agreed or strongly agreed that multicultural awareness should be taught in classrooms regardless of the background within the classroom. Only 3% of teachers believed teaching multicultural awareness in the classroom would cause conflict, a good sign especially in a largely diverse setting such as Head Start. A t-test looking at the differences in teachers who believed they had taught engineering previously and those that had not or were unsure was statistically significant, $t(62)=2.65$, $p=0.01$.

Perceived Professional Development Needs. This section of the survey instructed participants to prioritize different professional development needs from Not a priority (either because they were not interested or because they felt they were already qualified) to Essential.

The ranking ranged from 1 (Not a priority because I'm not interested) to 6 (Not a priority because I feel I'm qualified). Ratings 2 to 5 covered low priority, medium priority, high priority, and essential. The overall mean of the instrument was 3.96. Cronbach's alpha was 0.891. Table 19 (Appendix IIA) demonstrates the percentage that answered "High Priority" or "Essential". The highest percentage of teachers, 84%, marked "How to create meaningful activities to use in my pre-K classroom" as either a high priority or essential. Following closely, both at 81%, were "How to engage pre-k children in engineering lessons" and "How to make engineering concepts understandable to pre-K children". There was no statistically significant difference between teachers who believed they had taught engineering previously and those that had not or were unsure.

Classroom Breakdown. Teachers were asked to identify percentages of students in their classroom that were ethnic minorities, learning English as a second language, had specialized needs, from low-income households, born outside of the United States, or considered gifted children. They were given a scale from 1 (0%) to 5 (100%) that identified different ranges. Ninety-two percent of teachers reported having children from low-income families make up between 67% and 100% of their classroom. Table 20 (Appendix IIA) demonstrates the percentage of teachers who answered 67%-100% for each item. Seventy-three percent also indicated between 67% and 100% of children in their classroom were from ethnic minorities. Given that we are working with Head Start, these numbers are not extremely unpredictable, but the implication of these numbers, further discussed later, demonstrates the need for high-quality early childhood education.

Discussion

Examining the breakdown of the data from the online survey, there are clear areas that the Seeds of STEM project can empower within the Worcester Head Start classrooms. Overall, these teachers and teacher assistants come with a wide-range of experience and comfortability with STEM in the classroom, especially engineering. The researchers performed an independent t-test to look at the difference in means between those teachers that believed they had taught engineering previously and those that had not or were unsure. In areas such as frequency of engagement and encouragement of STEM activities, efficacy beliefs, and professional development needs, there was no significant difference. Interestingly, there was a statistically significant difference in multicultural attitudes and outcome expectancy beliefs between the two types of teachers. Over 90% of participants indicated in one item of the Teacher Multicultural Attitudes Survey they had positive attitudes towards multicultural students in the classroom, yet there was still a significant difference between the means of teachers who believed they had taught STEM previously and those that had not. Furthermore, 84% of teachers believed inadequacy in STEM could be overcome by good teaching, yet there still existed a difference of means for the instrument in those that believed they had taught STEM previously of not. These results in collaboration with the top professional development needs indicated in the survey informed the professional development created and administered to the teachers and teacher assistants.

Objective 2: Professional Development

As part of the Seeds of STEM project goals, the researchers created a series of professional development workshops aimed to help teachers feel more comfortable and confident in understanding and teaching engineering material on a preschool level. Three professional development seminars took place, each on two separate days so teachers and teacher assistants could both benefit from the sessions. The first was an introduction to engineering and the design process. The second was how to integrate high quality STEM activities into the preschool classroom. The third was concerning diversity in STEM and STEM education. All professional development materials are included in Appendix B.

Method

Participants

Thirty-one teachers and 32 assistant teachers consented to being a part of the Seeds of STEM study. Each of them were asked to attend three professional development programs. Any Worcester Head Start teachers or assistant teachers that had not consented to participating in the study could also attend the PD programs, but were not required to give feedback afterwards.

Sessions

Professional Development Session One. This session was specifically focused on introducing the ideas of STEM, engineering, and the engineering design process to the teachers and assistant teachers. The session included individual and group work to establish a preschool-level definition of STEM and engineering through discussion about the two topics. Further, teachers were able to watch a short video, perform an engineering-related challenge, and discuss how they had reached their solution as a way to understand, define, and apply the engineering design process.

Professional Development Session Two. This session introduced the idea of integrating high-quality STEM activities into the pre-kindergarten classroom. Teachers were asked to identify specific criteria for high-quality lessons regarding STEM in discussion with the grant team members. In small groups, they were then asked to design and conduct at least one activity.

Through discussion, they were able to make modifications to help teachers integrate the activities into their classrooms.

Professional Development Session Three. The final professional development session focused on the diversity factor of STEM and engineering, specifically how teachers can facilitate and empower minority students (women, differently abled, Blacks, Hispanics, etc.) to proceed with STEM in their future endeavors. Through a series of activities including Draw an Engineer, communication assessments, and true or false discussions, teachers worked together and were given recommendations on how to empower multiculturalism seamlessly in the curriculum.

Procedure

Each PD session was given two days in a row to allow both teachers and teacher assistants to be present at their convenience. Participants were led through a series of lessons on the topics specific to each sections, and completed activities based on those concepts. Session feedback surveys were distributed after the professional development seminar to gauge response to the material and concepts. Professional development feedback surveys and results are listed in Appendix IB.

Results

Professional Development Session One. Only 52 of the original 64 participated in the first professional development, introducing the engineering design process to preschool education. Questions on the feedback survey included "How much did this session help you better understand what STEM education is?", "How much did this session help you better understand what engineering is?", and "How much did this session help you learn about connections between the engineering design process and your daily classroom experience?". Eighty five per cent of teachers and teacher assistants answered "Much" or "Very Much" to the first question on the feedback survey. Similarly, 91% answered “Much” or “Very Much” to how much the session had helped them better understand engineering. And 81% answered “Much” or “Very Much” to how much the session had helped them see connections between the classroom and the engineering design process.

Professional Development Session Two. Only 43 of the original group of teachers and teacher assistants attended the second professional development. After each session, participants were asked “How much did this session help you better understand what the criteria are for a high quality STEM lesson/activity?”, “What are two criteria that distinguish a high quality STEM activity from a regular activity?”, and “To what extent do you feel you are leaving this session with a high quality STEM lesson/activity that you will be able to use in your classroom?”. Across both sessions, 83% of participants indicated the session helped them better understand the criteria for a high quality STEM activity “Much” or “Very Much”. Seventy-nine percent also indicated they “Much” of “Very Much” felt they were leaving with a high quality activity to implement in their classrooms. Interestingly though, only 33% could correctly indicate two of those criteria.

Professional Development Session Three. Forty-eight teachers and teacher assistants attended the third professional development session focused on diversity in STEM and STEM education. Questions on the feedback survey distributed at the end included, “How much did this session help you better understand why a STEM curriculum is needed at the pre-K level?”, “How much did this session help you better understand why diversity in the classroom is valuable?”, and “How much did this session help you learn how to be more culturally responsive in your classroom?”. Sixty-nine percent indicated the professional development seminar “Much” or “Very Much” helped them understand why STEM is needed in preschool. Of the total group, 84% indicated the session “Much” or “Very Much” helped them better understand the value of diversity in the preschool classroom. And finally, 75% indicated “Much” or “Very Much” concerning becoming more culturally responsive in the classroom.

Draw an Engineer. Before the start of the third professional development session, teachers were asked to draw an engineer at work. These drawings were analyzed for different traits such as race, gender, ability, and specific occupation (See Figures 3-7). Based on the analysis, most drawings depicted young men who were fully abled. In fact, not one drawing demonstrated a differently abled engineer. Race was hard to distinguish given the drawings were done in pencil and some included simple stick figures. However, the results did demonstrate default stereotypical views when drawing engineers, a stigma the researchers are working to change with intentionally inclusive and empowering professional development and curriculum.

Discussion

Overall, the implementation and results of the professional development sessions demonstrated that preschool teachers became more confident with STEM in the classroom after receiving some sort of training or activity aimed at building their knowledge and skills. Similarly, teachers felt more comfortable addressing and empowering diversity in the classroom, especially regarding STEM, after understanding the complexities around diversity and how valuable diversity can be to the preschool classroom.

Objective 3: Curriculum Development

Within the Seeds of STEM team, eight units of curriculum were created alongside the advisory board and the developer teachers. For the purposes of this project, only one sample unit of curriculum was created, Unit 8, which focuses on the engineering design process as a whole and solving problems using each step of the problem-solving method. Although this may not be used in the final product of Seeds of STEM, it was created demonstrate the possibilities of engineering curriculum for preschool children.

Method

The original proposal for the grant outlines the basic standards of the curriculum: 1) developmentally appropriate, 2) aligned with national and state STEM standards, 3) aligned with best practices of early childhood and STEM education, 4) culturally responsive and builds on children's real life experiences, 5) project-based, designed as integration of STEM practices with literacy, 6) include embedded, authentic assessment, 7) easy to use by early childhood teachers with no prior STEM background. To meet each of these criteria, Unit 8 was created using several resources, mainly the almost completed Unit 1 created by the grant team (Seeds of STEM, teacher developers, and advisory board members), the New Generation Science Standards (2015), and the Head Start Early Learning Outcomes Framework (2015).

Materials

The unit created alongside this paper, although only a sample, reflects the different materials that could potentially be used throughout all eight units. Specifically, the activities described require a large engineering design process wheel, arts and crafts materials, engineering related books, engineering badges (created in Unit 1 for each student), and chart paper. More or less materials could be used for each activity, based on different activities and the growth of the children throughout the course of the curriculum.

Design

Before creating Unit 8, the NGSS and Head Start Early Learning Outcomes were reviewed. The NGSS was broken down by grade level, starting at Kindergarten. Because the hope is this curriculum will not only build on preschool practices, but prepare children for more advanced STEM and engineering concepts, the researcher used the basic Kindergarten standards to inform the curriculum. Specific standards can be seen in the curriculum unit (Appendix IC). Furthermore, the Head Start Early Learning Outcomes was differentiated by infant/toddler and preschool aged children. Although there will be some children participating that are closer to toddler age, the researchers focused on the outcomes described for preschool children. For example, some of these early learning outcomes include “child engages in scientific talk”, “child demonstrates flexibility in thinking and behavior”, and “child plans and conducts investigations and experiments”.

Unit 8 is comprised of four activities that each engage children with the entire engineering design process in an effort to solve problems relevant to their lives. Vocabulary is defined in the beginning of the curriculum and ideally is built on the vocabulary learned in Units 1 through 7. Additionally, there are built in assessments that inform teachers about how students are comprehending and critically analyzing the material, and family connections aimed to include family in the lessons being discussed at school. Using the NGSS and the Head Start Early Learning Outcomes Framework as a baseline, Unit 8 is a culturally and developmentally appropriate unit of curriculum that is easy to use and builds on STEM in the preschool classroom.

General Conclusion

The Seeds of STEM project aimed to identify preschool teacher practices and needs, create a professional development for teachers, and develop an appropriate engineering curriculum for preschool children. Using the teacher survey, teachers’ practices and needs were identified and used to inform the creation of three professional development sessions. National science and Head Start standards were reviewed and utilized to create a developmentally and culturally appropriate curriculum encompassing the engineering design process.

The teacher survey measured teacher's classroom procedures, teacher efficacy, expectancy beliefs, multicultural attitudes, professional development needs, and basic demographic information. Most teachers indicated use of STEM practices in the classroom, confidence with STEM material at a preschool level, and prioritized professional development in making engineering concepts understandable to preschool children, engaging preschoolers with STEM material, and integrating high-quality STEM activities into the classroom. Teachers were also asked whether or not they believed they had taught engineering at the preschool level previously. Based on t-tests between the two groups, there was a statistically significant difference in expectancy beliefs and multicultural attitudes. Teachers who believed they had taught engineering previously demonstrated higher expectancy beliefs, meaning they understood their role in student success, specifically in STEM education. They also had more tolerant and inclusive views of diverse classrooms. Using these results, the three professional development sessions were created: an introduction to STEM education and preschool, integrating high-quality STEM activities into the classroom, and empowering diversity in STEM education. After reviewing national science and Head Start standards, a sample of Unit 8 was created and demonstrates possibilities for future units created by the grant team.

With the understanding that 3 to 5 year olds are explorative and critically thinking of the world around them, coupled with the benefits of preschool and the need for early STEM education interventions, Seeds of STEM has started to develop a curriculum and professional development package that has the potential to increase STEM engagement from a young age while simultaneously debunking stereotypes and stigmas of engineering and diversity.

Professional development focused on the engineering design process, the integration of high quality STEM activities into the classroom, and the empowerment of diversity in STEM and STEM education has shown to be successful in increasing understanding about engineering in the preschool classroom and how diversity is valuable. Furthermore, the development of Unit 8 of the engineering curriculum demonstrates the potential success students can have with engineering at an early education level.

Limitations of the study included a lack of post-test data for teachers' attitudes and a lack of pre- and post-test data for children's assessment. Specifically concerning Unit 8, there is no data collection to be analyzed for feedback regarding the activities and structure, as the unit is only a sample. Although limitations currently exist in the project methods, the piloting stage of the grant may provide opportunity to gather this data and obtain experimentally sound results regarding engineering education at the preschool level.

Future research for the grant team includes finishing the development of all 8 units of curriculum and pilot testing with other Head Start programs around the Massachusetts area and the creation of future professional developments. Further, pre and post-test data will be collected from piloting teachers and students to evaluate teacher and student outcomes. Fidelity of implementation and assessment of each area of the curriculum and professional development will also occur so curriculum and professional developments can be analyzed and improved, before being finalized. The ultimate goal of the grant team is to widely disseminate this curriculum, making it a staple in preschool classrooms nation-wide.

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Appendix I: Instruments

Appendix IA. Initial Teacher Survey

TEACHER'S ENGINEERING INSTRUCTION

1. During the time you spend in the pre-k classroom, how often do your children engage in the following tasks?

"STEM Instruction tool" from Golden Leaf STEM Initiative Evaluation

	1 Never	2 Rarely	3 Sometimes	4 Often	5 Very Often
Develop problem-solving skills through investigations					
Work in small groups					
Make predictions that can be tested					
Make careful observations or measurements					
Use tools to gather data (e.g. scales, rulers, non-standard units, etc.)					
Recognize patterns in data					
Create reasonable explanations of results of an experiment or investigation					
Choose variety of methods to express results (e.g. drawings, models, charts, etc.)					
Complete activities with a real-world context					
Engage in content-driven dialogue					
Reason abstractly					
Reason quantitatively					
Critique the reasoning of others					

Learn about careers related to the instructional content					

Adapted from Faber, M., Walton, M., booth, S., Parker, B., Corn, J., & Howard, E. (2013). The Golden Leaf STEM Evaluation, Appendix D. *Science, Technology, Engineering, Mathematics, and Elementary Teacher Efficacy and Attitudes toward STEM (T-STEM) Surveys. Available at: http://cerenc.org/wp-content/uploads/2011/11/FI_GLFSTEMYearTwoAppendices_May2013_FINAL.pdf*

2. During the time you spend in the pre-k classroom, how frequently do you encourage children to do each of the following in your work with them?

"STEM Engagement" Self-created Instrument

	1 Never	2 Rarely	3 Sometimes	4 Often	5 Very Often
Ask questions about things in the natural world they see around them					
Design things during a lesson					
Plan investigations					
Carry out investigations					
Come up with explanations about why things might happen or why things did happen in a particular way					
Change explanations based on new information					
Talk with you or other educators about investigations					
Talk and collaborate with their peers to solve problems					
Apply their past experiences to new situations or investigations					
Describe real world problems/problems relevant to children's own lives					
Brainstorm/seek multiple solutions to a problem					
Come up with solutions to real world problems/problems relevant to children's own lives					
Use a variety of ways to represent (model) a solution or idea					
Use models to test explanations					

3. Please respond to these questions regarding your feelings about teaching.

"STEM Teaching Outcome Expectancy Beliefs (STOES)"

	1 Strongly Disagree	2 Disagree	3 Neither agree or disagree	4 Agree	5 Strongly Agree
When a child does better than usual in STEM, it is often because the educator exerted a little extra effort.					
The inadequacy of a child's STEM background can be overcome by good teaching.					
When a child's learning in STEM is greater than expected, it is most often due to their educator having found a more effective teaching approach.					
The educator is generally responsible for childrens' learning in STEM.					
If childrens' learning in STEM is less than expected, it is most likely due to ineffective STEM teaching.					
Children's learning in STEM is directly related to their educator's effectiveness in STEM teaching.					
When a low achieving child progresses more than expected in STEM, it is usually due to extra attention given by the educator.					
If parents comment that their child is showing more interest in STEM at school, it is probably due to the performance of the child's educator.					
Minimal child learning in STEM can generally be attributed to their educators.					

This scale was developed from the STEBI (Science Teaching Efficacy Beliefs Instrument). Enochs, L.G. & Riggs, I. (1990). Further development of an elementary science teaching efficacy belief instrument: A preservice elementary scale. School Science and Mathematics, 90, 694-706

4. Do you currently teach – or have you ever taught – engineering to pre-k children?
    a. Yes
    b. No

5. Please respond to these questions regarding your feelings about your own teaching.
"Personal Engineering Teaching Efficacy and Beliefs"

	1 Strongly Disagree	2 Disagree	3 Neither agree or disagree	4 Agree	5 Strongly Agree
I am continually improving my engineering teaching practice					
Given a choice, I would invite a colleague to evaluate my engineering teaching					
When a child has difficulty understanding an engineering related concept, I am confident that I know how to help the child understand it better					
When teaching engineering, I am confident enough to welcome childrens' questions					

Adapted from Faber, M., Walton, M., booth, S., Parker, B., Corn, J., & Howard, E. (2013). The Golden Leaf STEM Evaluation, Appendix D. *Science, Technology, Engineering, Mathematics, and Elementary Teacher Efficacy and Attitudes toward STEM (T-STEM) Surveys. Available at: http://cerenc.org/wp-content/uploads/2011/11/FI_GLFSTEMYearTwoAppendices_May2013_FINAL.pdf*
Note: STEM was changed to engineering
Original reference: This scale was developed from the STEBI (Science Teaching Efficacy Beliefs Instrument). Enochs, L.G. & Riggs, I. (1990). Further development of an elementary science teaching efficacy belief instrument: A preservice elementary scale. School Science and Mathematics, 90, 694-706.

6. Please respond to these questions regarding your feelings regarding your own teaching.
"Efficacy and Beliefs" Instrument

	1 Strongly Disagree	2 Disagree	3 Neither agree or disagree	4 Agree	5 Strongly Agree
I know the steps necessary to teach engineering effectively					
I am confident that I can explain to children why engineering experiments work					
I am confident that I can teach engineering effectively					
I wonder if I have the necessary skills to teach engineering					
I understand engineering concepts well enough to be effective in teaching engineering					
I am confident that I can answer childrens' engineering questions					
I know what to do to increase childrens' interest in engineering.					

Adapted from Faber, M., Walton, M., booth, S., Parker, B., Corn, J., & Howard, E. (2013). The Golden Leaf STEM Evaluation, Appendix D. *Science, Technology, Engineering, Mathematics, and Elementary Teacher Efficacy and Attitudes toward STEM (T-STEM) Surveys. Available at:* http://cerenc.org/wp-content/uploads/2011/11/FI_GLFSTEMYearTwoAppendices_May2013_FINAL.pdf
Note: STEM was changed to engineering
Original reference: This scale was developed from the STEBI (Science Teaching Efficacy Beliefs Instrument). Enochs, L.G. & Riggs, I. (1990). Further development of an elementary science teaching efficacy belief instrument: A preservice elementary scale. School Science and Mathematics, 90, 694-706.

7. Please answer the following questions based on your ideas and thoughts about teaching.

"Teacher Multicultural Attitude Survey"

Item	1- Strongly disagree	2- Disagree	3- Neither disagree nor agree	4- Agree	5- Strongly Agree
I find the idea of teaching a culturally diverse group rewarding.					
Teaching methods need to be adapted to meet the needs of a culturally diverse student group					
Sometimes I think there is too much emphasis placed on multicultural awareness and training for teachers.					
Teachers have the responsibility to be aware of their students' cultural backgrounds.					
It is the teacher's responsibility to invite extended family members (e.g., cousins, grandparents, godparents, etc.) to attend parent-teacher conferences.					
It is not the teacher's responsibility to encourage pride in one's culture					
As classrooms become more culturally diverse, the teacher's job becomes increasingly challenging.					
I believe the teacher's role needs to be redefined to address the needs of students from culturally different backgrounds.					
When dealing with bilingual students, some teachers may misinterpret different communication styles as behavior problems.					

As classrooms become more culturally diverse, the teacher's job becomes increasingly rewarding.					
I can learn a great deal from students with culturally different backgrounds.					
Multicultural training for teachers is not necessary.					
In order to be an effective teacher, one needs to be aware of cultural differences present in the classroom.					
Multicultural awareness training can help me work more effectively with a diverse student population.					
Students should learn to communicate in English only.					
Today's curriculum gives undue importance to multiculturalism and diversity					
I am aware of the diversity of cultural backgrounds of students I am/or will be working with.					
Regardless of the racial and ethnic make up of a classroom class, it is important for all students to be aware of multicultural diversity.					
Being multiculturally aware is not relevant for students.					
Teaching students about cultural diversity will only create conflict in the classroom.					

The twenty-statement Teacher Multicultural Attitude Survey (TMAS; Ponterotto, Mendelsohn, and Belizaire 2003), which uses a 5 point Likert scale, was given as a pre- and post-test to measure the teacher candidates' sensitivity to and familiarity with multicultural issues as well as to determine if the course curriculum affected students' multicultural awareness positively. The construct and criterion validity and reliability of the developed TMAS are supported (Ponterotto et al., 1998).

8. For purposes of completing the items on this page, assume that teaching engineering is something that you are supposed to be doing in your pre-K classroom. Given that, for each of the following areas, use the rating scale to indicate how much of a priority it would be for you to get professional development in that area.

"Perceived PD Needs"

	Not a priority because I'm not interested	Not a priority because I feel qualified	Low priority	Medium Priority	High Priority	Essential
Professional Development Needs						
Information about how to teach engineering to a diverse group of pre-K children						
Classroom management						
Communicating with families and caregivers about how to support children's engineering learning at home						
How to plan engineering lessons for pre-K children						
Background knowledge about what engineering is						
Information about how to teach engineering to pre-K children, in general						
How to create meaningful activities to use in my pre-K classroom						
How to get engineers or engineering role models to visit my classroom						
How to engage pre-K children in engineering lessons						
How to make engineering concepts understandable to pre-K children						
Background knowledge about what STEM is						
Background knowledge about the relationship between engineering and STEM						

Demographics

9. Which of the following best describes your position at your school?
   a. Lead preschool teacher
   b. Preschool teacher assistant

10. Using the rating scale, please indicate how many children in your current pre-K class are from each of the following groups.

	0%	1-33%	34-66%	67-99%	100%
Students who are ethnic minorities					
Students whose first language is not English					
Children with specialized learning needs					
Children from low-income families					
Children born outside of the U.S.					
Gifted students					

Adapted from APA Teacher Needs Survey found https://www.apa.org/ed/schools/coalition/teachers-needs.pdf

11. What is your age?
    a. 18-24 years old
    b. 25-34 years old
    c. 35-44 years old
    d. 45-54 years old
    e. 55-64 years old
    f. 65-74 years old
    g. 75 years or older

12. What is your sex?
    a. Male
    b. Female

13. Were you born in the U.S.?
    a. Yes
    b. No

14. What is your race or ethnicity?
    a. Arab, Arab American, or Middle Eastern
    b. Asian, Asian American, Oriental, or Pacific Islander
    c. Black, African, or African American
    d. Black, Caribbean Islander, or West Indian
    e. Hispanic or Latino
    f. White, Caucasian, European, not Hispanic
    g. American Indian
    h. Multiracial/Multiethnic/Multinational
    i. Other

15. Do you consider English to be your primary spoken language?
    a. Yes, and I primarily speak English in my everyday/daily life
    b. Yes, but I regularly speak another language/other languages in my everyday/daily life
    c. No, I speak another language/other languages in my everyday/daily life

16. Please identify any other languages you speak.

Teacher Educational Background

17. Please check any grades/groups that you currently or have previously taught.

- o PK Birth to 1
- o PK 1 to 2 year old
- o PK 2 to 3 year old
- o PK 3
- o PK 4
- o Kindergarten
- o Grade 1
- o Elementary grades about Grade 1
- o Middle School
- o High School
- o Adult Learners

18. How many years of teaching experience do you have?

- o First year teaching
- o Two years
- o Three years
- o Four years
- o Five to ten years
- o More than ten years

19. How many years of teaching experience at the pre-K level do you have?

a. First year
b. Two years
c. Three years
d. Four years
e. Five to ten years
f. More than ten years

20. Highest level of education completed

a. Less than high school
b. High school/GED
c. Some college
d. 2 year college (Associates degree)
e. 4 year college (BA, BS)
f. Master's degree
g. Doctoral degree
h. Professional degree (MD., JD)

21. In what type of program were you prepared as a teacher specifically
    - o As part of an early childhood community college program
    - o As part of a bachelor's degree program
    - o As part of a five year program
    - o As part of a master's degree program
    - o As part of alternative route to certification (e.g. Teach for America, State sponsored, etc.)
    - o Other (please specify) ______________________________________

22. Are you certified or licensed in your state?
    - o Not yet licensed/certified
    - o Provisional license/certification
    - o Licensed/certified up to four years or less
    - o Licensed/certified for five or more years
    - o Others, please specify: ____

23. If you are certified, please indicate whether you have special or regular certification

Adapted from APA Teacher Needs Survey found https://www.apa.org/ed/schools/coalition/teachers-needs.pdf

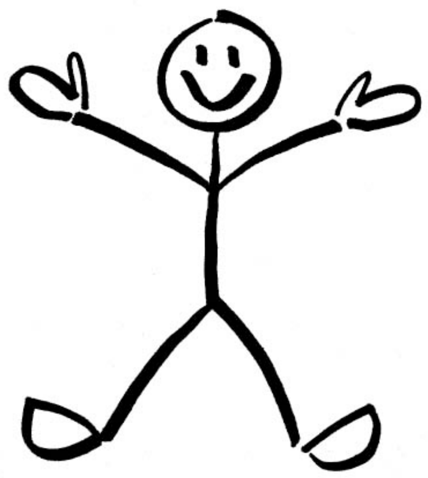
Appendix IB. Professional Development

Melissa-Sue John, Ph.D.

WORCESTER POLYTECHNIC INSTITUTE 1865

ies INSTITUTE OF EDUCATION SCIENCES

Activity #1: Draw an Engineer at Work



Diversity in Engineering

Professional Development

Mill Swan A Head Start

April 6, 2016

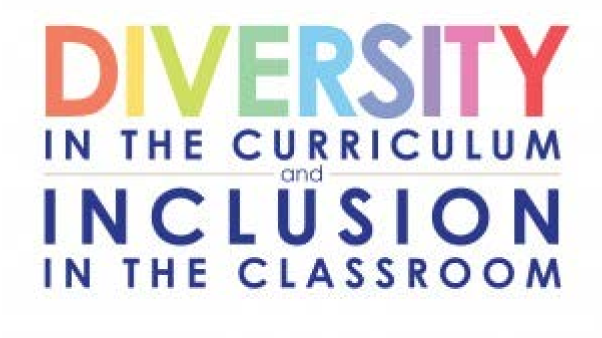
Agenda

- Purpose
- Background
- Definitions
- Recommendations and Applications

Purpose

To discuss the need for and ways to increase diversity

in the S.T.E.M. curriculum at the Pre-K level



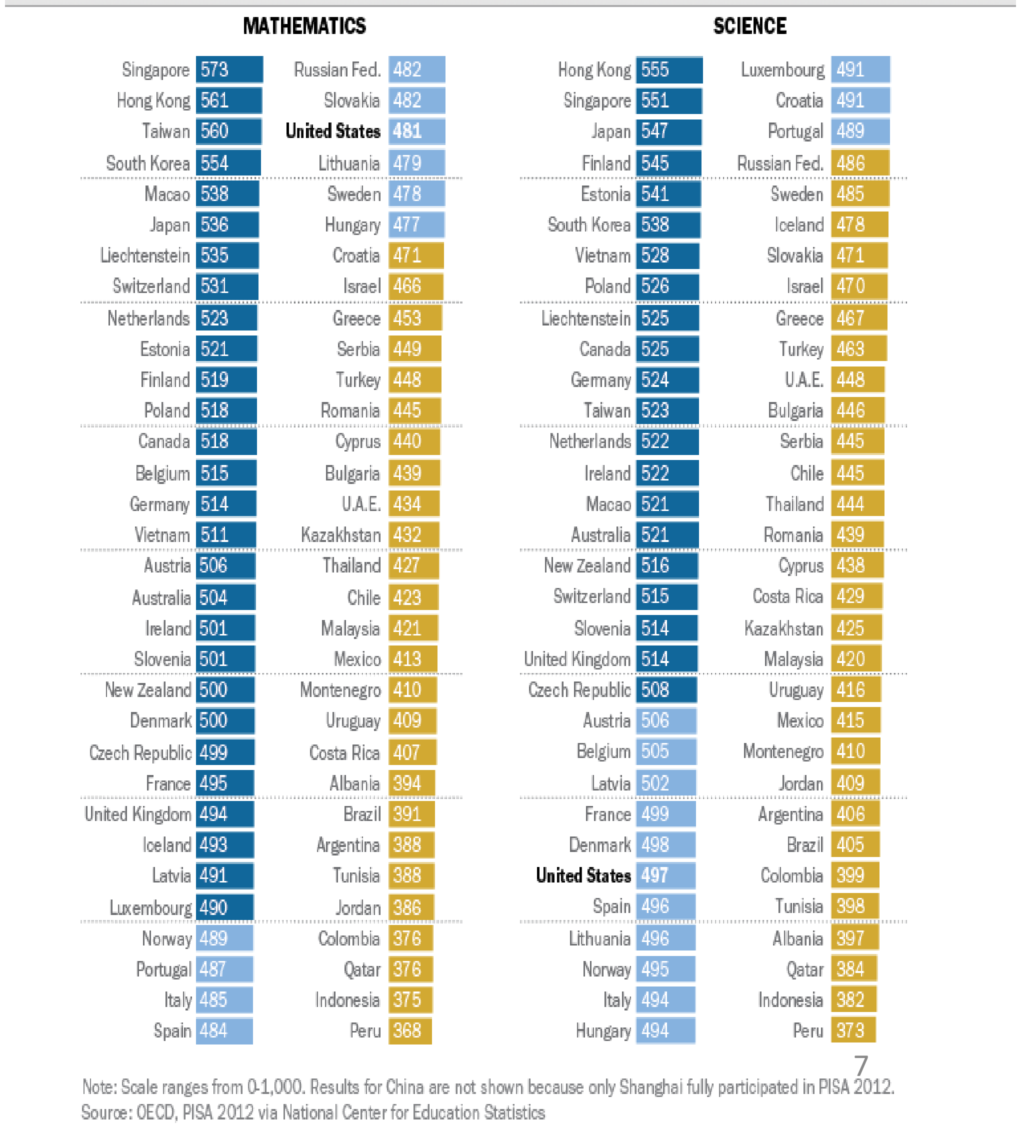
BACKGROUND

Problems in S.T.E.M.

- Great accomplishments in the 20th century
  - The first man on the moon
  - Polio vaccine
  - Internet
  - Institutions like MIT, Caltech, WPI, and Berkeley

- The U.S. is falling behind other nations
  - 17 out of 19 countries in Problem Solving
  - 21 out of 23 countries in Math
  - 30 of the 40 most advanced countries graduating science majors

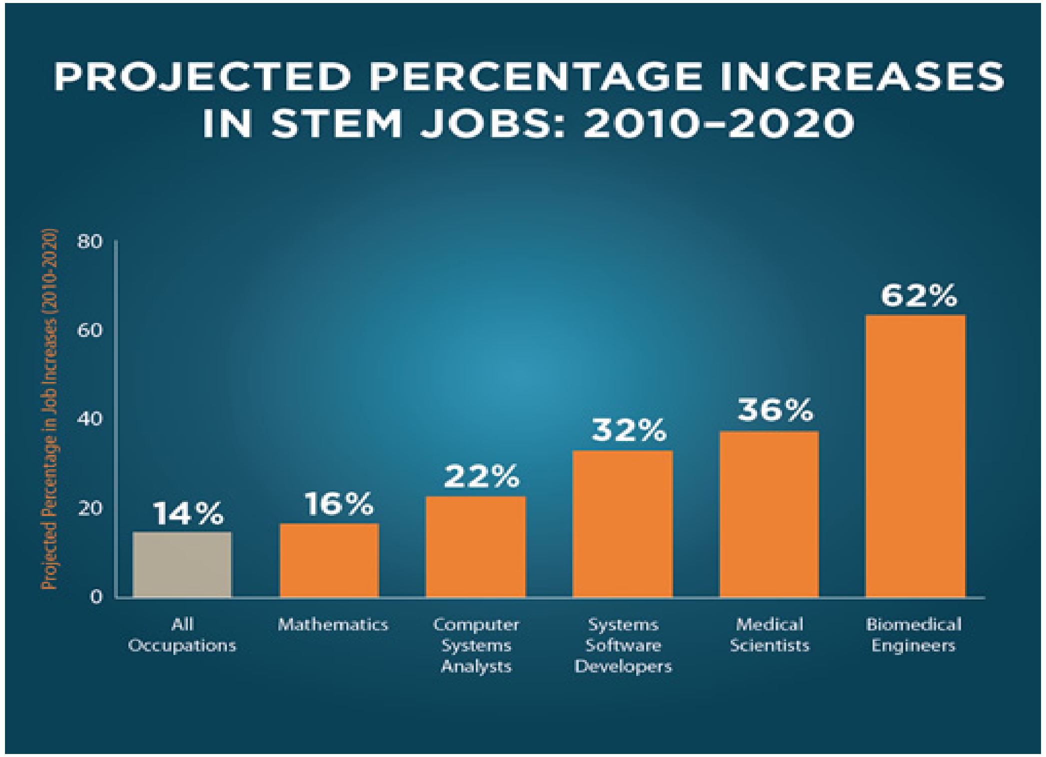
National Center for Education Statistics, 2012; Pew Research, 2015



S.T.E.M. Problems

- Millions of S.T.E.M. jobs are available
  - Not filled because of lack of qualified STEM workers

- The Engineering workforce
  - 87% Whites and Asians compared to 12% African Americans and Latinos
  - 24% are women



Bennett, 2012; *Change the Equation*

How do we solve the STEM Dilemma?

Solving the STEM Dilemma

- Pipeline interventions or Bridge programs

  Elementary school → Middle school → High school → College→ Work Force

- *High quality curriculum*
- *Early education (pre-K)*
- ***Diversity***

MARC
Maximizing Access to Research Careers
The MARC U*STAR Program at UCLA

RISE

SUMR

STEM SUMMER BRIDGE PROGRAM

Why Diversity?

Consider the diverse composition of your classrooms

- Does it match K-12 classrooms? College?
- Does it match the diversity of STEM occupations?

Why Diversity?

1. Diversity is critical to excellence

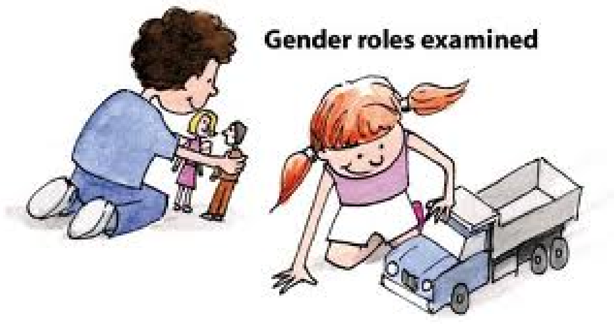
2. Lack of diversity represents a loss of talent

3. Enhancing diversity is key to long-term economic growth and global competitiveness

DEFINITIONS

Gender

- *Sex*- the genetic determination of being male or female
- *Gender*- the socially defined roles expected of male and female human beings



Nationality

- The status of belonging to a particular nation by origin, birth, or naturalization
- E.g. American, Jamaican, Italian, Brazilian, Polish, etc.

Ethnicity

- denotes a group of people who perceive themselves and are perceived by others as sharing cultural traits
- Includes language, religion, family customs, and diet

Race

- denotes a group of people who perceive themselves and/or are perceived by others as possessing distinctive physical traits
- Often based on skin color and other characteristics.
- E.g., White, Black, Yellow, or Red

Racial Identity

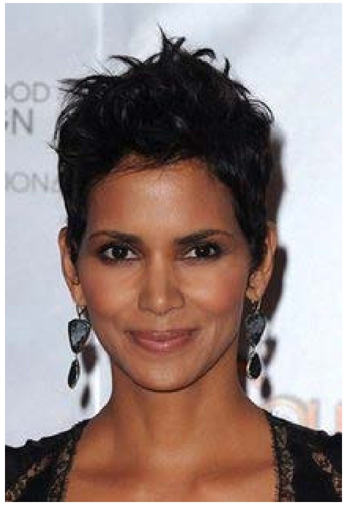
- one's sense of group identity or affiliation and association with others who possess the same racial heritage.

Rachel Dolezal

Raven Symoné

Diandra Forrest

Winnie Harlow



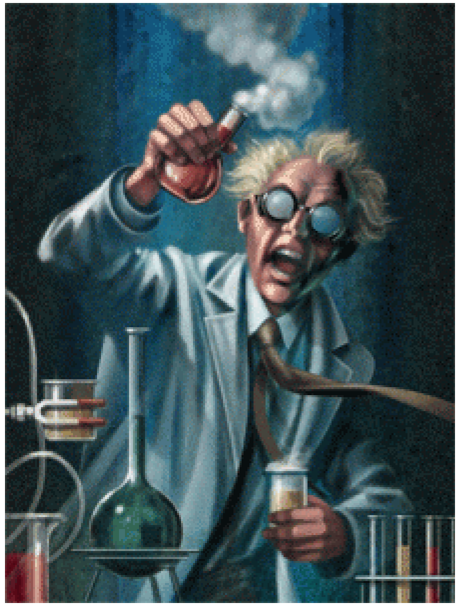
Halle Berry

Cultural Proficiency

Learning and teaching about different groups in ways that acknowledge and honor all people and the groups they represent.

Stereotypes

- A set of beliefs about the personal attributes of a group of people
- May be positive or negative
- Examples?



Activity #2: Case Study

Richie Parker

Summary

- Identifies as:
  - **Car enthusiast**
  - **Engineer**
  - **Employee**
  - **Son**
- He also happens
  - To be **male (gender)**
  - To have **no arms** due to a condition known as Bilateral Amelia in which limbs aren't formed **(ability)**
  - To be **African American (race and Nationality)**

Activity #2: Case Study

- How does this change your perception of
  - What an engineer at the job looks like?
  - What diversity means?
  - What are the different types of diversity we should include?

Diversity

- Age
- Gender
- Race
- Culture

- Nationality
- Socioeconomic
- Cognitive abilities
- Physical abilities

RECOMMENDATIONS & PRACTICAL APPLICATIONS

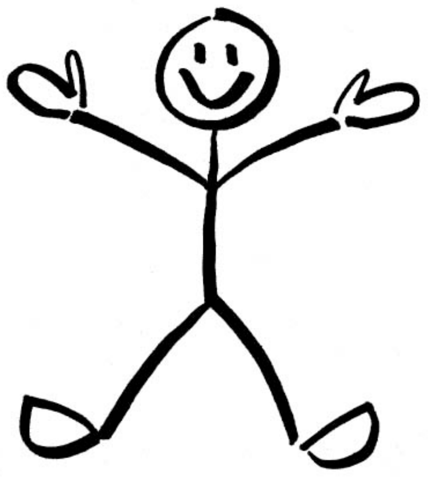
Discussion

- What are the practices you currently use to be culturally responsive?

- How can we make the curriculum more inclusive?

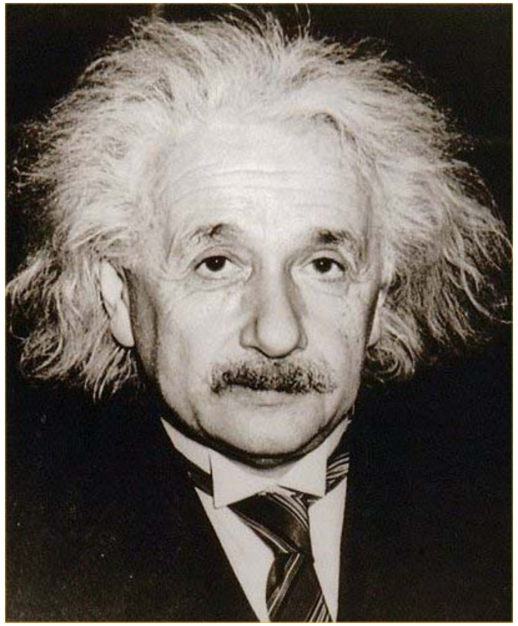
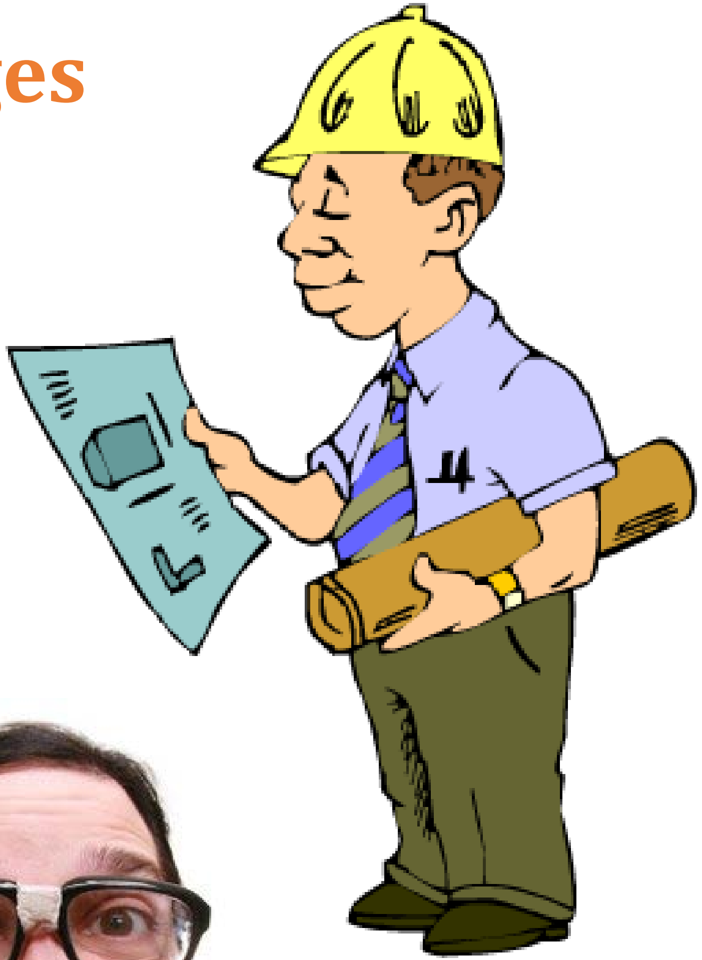
Activity #3: Group Activity

- Compare your drawings of the engineers at work
- Discuss the following. Was there…
  - Gender diversity?
  - Racial and ethnic diversity?
  - Age diversity?
  - Occupational diversity?
  - Ability diversity?
  - Stereotypes?



- Share

Stereotypical Images



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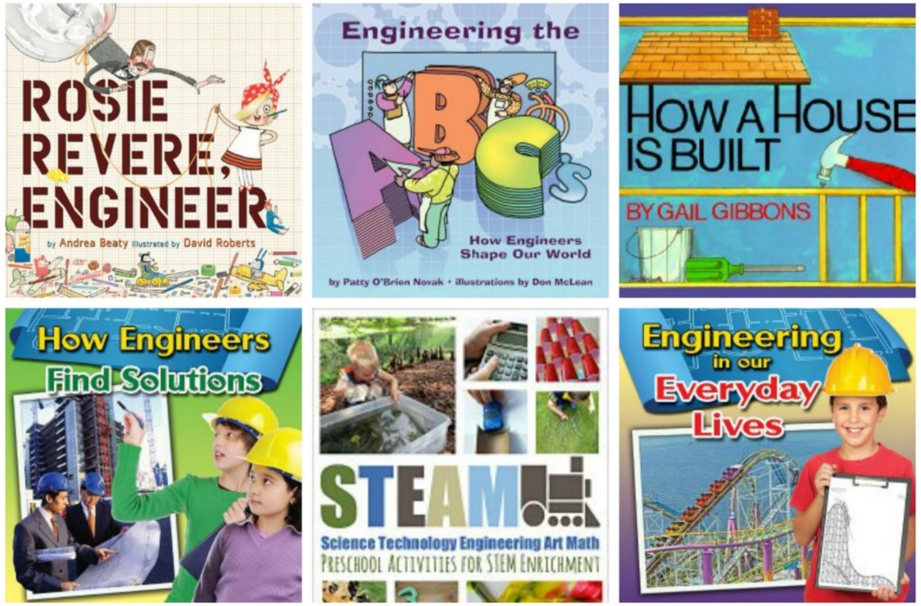
Diversity in Engineering

Recommendation #1

Be aware of our personal biases

Application #1

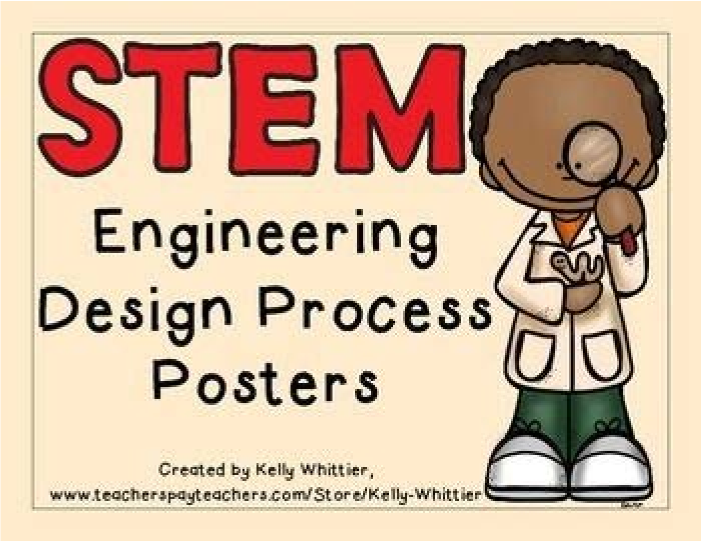
Be deliberate in one's choices: **Books**

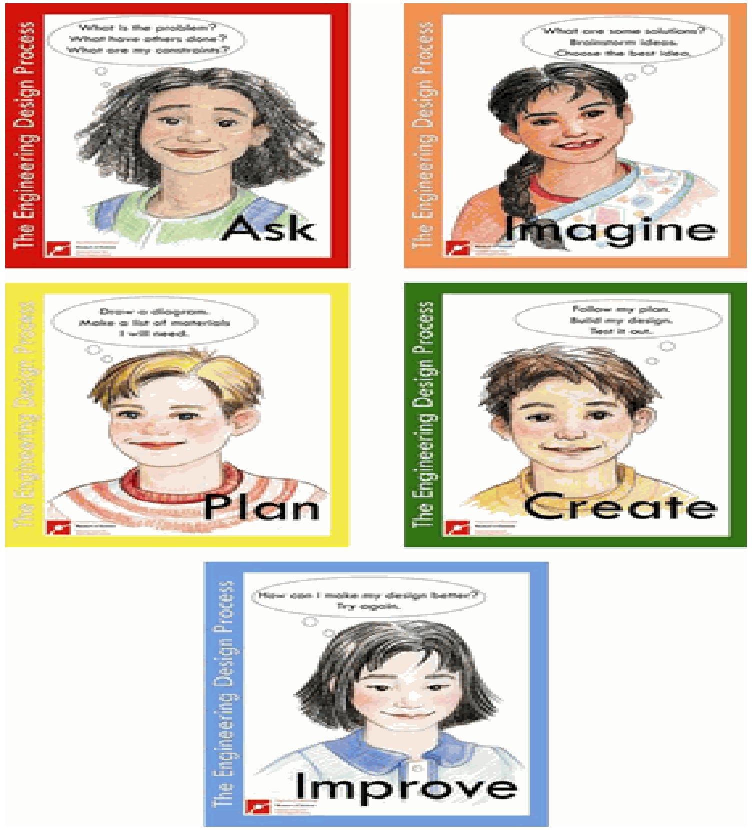


Be inclusive of gender, race, disability, and different engineering occupations

Application #1a

Be deliberate in one's choices: **Posters**





Julia Beecherl Endowed Professor
Founder / Director of Nanotechnology
Center of Excellence

Application #1

Emily Warren Roebling one of the engineers of the Brooklyn Bridge

Mae C. Jemison

President's Council of Advisors on Science and Technology (PCAST) in President Barack Obama's administration.

Sundar Pichai is a computer engineer and the current CEO of Google Inc.

Share Videos of Role Models

Application #1a

Be deliberate in one's choices: **Guest Speakers**

- Parents
- Community Workers
- Experts in the field

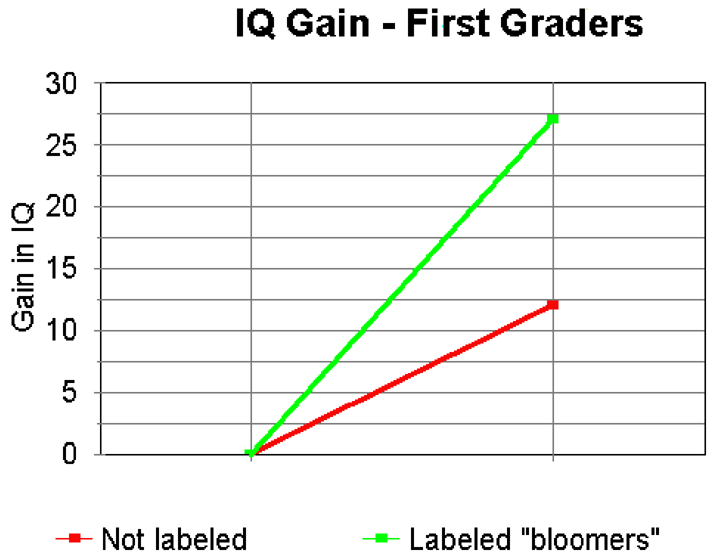
Recommendation #2

- Be aware of our beliefs

Expectancy Beliefs

Do teacher's expectations actually influence student performance?

- Rosenthal & Jacobsen (1968) Study
- Teachers informed that some students were “bloomers” based on IQ test
- “Bloomers” actually scored an average of 30 points higher on standardized tests



High vs. Low Expectations

- Identifying problems
- Waiting for answers
- Role play

Application #2

- Foster respect in classroom
- Hold all students to high standards
- Make learning challenging
- Encourage creativity
- Engage all learners

Recommendation #3

- Learn about our own culture and about others

Celebrating Diverse Cultures

1. Attend cultural events in your community
2. Develop relationships and understand the dynamics of cultural interactions
3. Make connections between classroom and real world
   - Include books, language, diet of different cultures
   - Choose examples that are relevant to students (TV, online, film, current events)
   - Have Show and Tell
   - Involve families and communities

Head Start Cultural and Linguistic Responsiveness

Respecting Diverse Cultures

1. How do my children and parents self-identify?
2. What are their nationalities?

   Mexican vs. Puerto Rican

   Jamaican vs Trinidadian

   Polish vs Ukrainian

   Korean vs Japanese

3. What do they prefer to be called?

   Black vs African American

   Latino vs Hispanic American

   White vs Caucasian vs European American

   Asian vs Asian American

Incorporating Diverse Cultures

Summary

1. Be aware of personal biases
   - Use inclusive pedagogical content (books, posters, activities)
2. Be aware of one's beliefs
   - Foster respect in classroom
   - Engage and challenge all learners
3. Learn about our own culture and about other cultures
   - Attend cultural events in your community
   - Develop relationships and understand the dynamics of cultural interactions
   - Involve families and communities

Session Feedback Results

Session One- Introduction to STEM Education

Table 1: What is your position?

	December 14		December 16		Both Sessions	
Position	n	%	n	%	n	%
Assistant Teacher	14	52%	11	44%	25	48%
Teacher	12	44%	12	48%	24	46%
Did not indicate	1	4%	2	8%	3	6%
Total	27	100%	25	100%	52	100%

Table 2: How much did this session help you better understand what STEM education is?

	December 14		December 16		Both Sessions	
Extent Session Helped	n	%	n	%	n	%
Not at all	0	0%	0	0%	0	0%
Just a little bit	1	4%	0	0%	1	2%
Somewhat	5	19%	2	8%	7	14%
Much	14	52%	16	64%	30	58%
Very much	7	26%	7	28%	14	27%
Total	27	100%	25	100%	52	100%

Table 3: How much did this session help you better understand what engineering is?

	December 14		December 16		Both Sessions	
Extent Session Helped	n	%	n	%	n	%
Not at all	0	0%	0	0%	0	0%
Just a little bit	1	4%	0	0%	1	2%
Somewhat	3	11%	1	4%	4	8%
Much	14	52%	14	56%	28	54%
Very much	9	33%	10	40%	19	37%

Total	27	100%	25	100%	52	100%

Table 4: How much did this session help you better understand the connection between the engineering design process and your daily classroom experience?

	December 14		December 16		Both Sessions	
Extent Session Helped	n	%	n	%	n	%
Not at all	0	0%	0	0%	0	0%
Just a little bit	2	7%	0	0%	2	4%
Somewhat	2	7%	6	24%	8	15%
Much	14	52%	13	52%	27	52%
Very much	9	33%	6	24%	15	29%
Total	27	100%	25	100%	52	100%

Session Two- Integrating High Quality STEM Activities

Table 5: What is your position?

	December 14		December 16		Both Sessions	
Position	n	%	n	%	n	%
Assistant Teacher	8	42%	11	46%	19	44%
Teacher	11	58%	12	50%	23	53%
Did not indicate	0	0%	1	4%	1	2%
Total	19	100%	24	100%	43	100%

Table 6: How much did this session help you better understand what the criteria are for a high quality (HQ) STEM lesson/activity?

	December 14		December 16		Both Sessions	
Extent Session Helped	n	%	n	%	n	%
Not at all	0	0%	0	0%	0	0%
Just a little bit	3	16%	0	0%	3	7%
Somewhat	2	11%	2	9%	4	10%
Much	10	53%	16	70%	26	62%
Very much	4	21%	5	22%	9	21%
Total	19	100%	23	100%	42	100%

Table 7: What are two criteria that distinguish a HQ STEM activity from a regular activity?

	December 14		December 16		Both Sessions	
Number correct (of 2)	n	%	n	%	n	%
0	7	37%	9	38%	16	37%
0.5 to 1.5	5	26%	8	33%	13	30%
2	7	37%	7	29%	14	33%
Total	19	100%	24	100%	43	100%

Table 8: To what extent do you feel you are leaving this session with a HQ STEM lesson/activity that you will be able to use in your classroom?

	December 14		December 16		Both Sessions	
Extent Session Helped	n	%	n	%	n	%
Not at all	4	21%	0	0%	4	9%
Just a little bit	0	0%	0	0%	0	0%
Somewhat	4	21%	1	4%	5	12%
Much	7	37%	17	71%	24	56%
Very much	4	21%	6	25%	10	23%
Total	19	100%	24	100%	43	100%

Session 3- Diversity in STEM Education

Table 9: What is your position?

	December 14		December 16		Both Sessions	
Position	n	%	n	%	n	%
Assistant Teacher	14	61%	5	20%	19	40%
Teacher	6	26%	19	76%	25	52%
Did not indicate	3	13%	1	4%	4	8%
Total	23	100%	25	100%	48	100%

Table 10: How much did this session help you better understand why at STEM curriculum is needed at the preschool level?

	December 14		December 16		Both Sessions	
Extent Session Helped	n	%	n	%	n	%
Not at all	0	0%	1	4%	1	2%
Just a little bit	0	0%	2	8%	2	4%
Somewhat	3	13%	9	36%	12	25%
Much	10	43%	8	32%	18	38%
Very much	10	43%	5	20%	15	31%
Total	23	100%	25	100%	48	100%

Table 11: How much did this session help you better understand why diversity in the classroom is valuable?

	December 14		December 16		Both Sessions	
Extent Session Helped	n	%	n	%	n	%
Not at all	0	0%	1	4%	1	2%
Just a little bit	0	0%	2	8%	2	4%
Somewhat	3	13%	2	8%	5	10%
Much	8	35%	11	44%	19	40%
Very much	12	52%	9	36%	21	44%
Total	23	100%	25	100%	48	100%

Table 12: How much did this session help you learn how to be more culturally responsive in your classroom?

	December 14		December 16		Both Sessions	
Extent Session Helped	n	%	n	%	n	%
Not at all	0	0%	1	4%	1	2%
Just a little bit	0	0%	1	4%	1	2%
Somewhat	4	17%	6	24%	10	21%
Much	10	43%	11	44%	21	44%
Very much	9	39%	6	24%	15	31%
Total	23	100%	25	100%	48	100%

Appendix IC. Curriculum Development

Seeds of STEM curriculum

Unit 8 Draft 1

Engineering Design Process in Action!

Big idea:

Incorporating entire Engineering Design Process into problem solving within and outside the classroom.

Learning Outcomes:

- Students understand how to successfully use the process to problem solve
- Students use vocabulary presented throughout the units properly and appropriately
- Students can identify each step of the process

Vocabulary:

- Unit 1:
  - Problem
  - Solve/solving
  - Solution
  - Engineer
- Unit 2:
  - Brainstorm
  - Solution
  -
- Unit 3:
  - Compare
  - Alternative
  - Describe
- Unit 4:
  - Design
  - Model
  - Build
- Unit 5:
  - Test
  - Improve
  - Compare
- Unit 6:
  - Explain

  - Describe
- Unit 7:
  - Engineering Design Process
  - Engineer
- Unit 8:
  - All previous vocabulary

Process:

- Identify and describe problem
- Brainstorm solutions
- Compare and Choose best solution
- Design and build a model
- Test solution and improve it
- Explain solution to others

Materials & resources:

- Engineering Design Process Wheel
- Books used in previous Units
- Engineer Badges
- Arts and crafts materials (paper, pencils, markers, crayons, etc.)
- Engineering songs
- Chalk/white/paper board

Preparation:

- Ensure students understand and are capable of performing each step of the process
- Review engineering design process before activities
  - Review the engineering design process wheel

Instructions/background information:

NGSS Framework:

K-PS2-1: Plan and construct an observation

K-PS2-2: Analyze data to determine if design solution works as intended

K-ESS2-1: Use and share observations to describe patterns over time

K-ESS2-2: Construct an argument supported by evidence

K-ESS3-1: Use a model to represent relationships

K-ESS3-2: Ask questions to obtain information

K-ESS3-3: Communicate solutions

K-LS1-1: Use observation to describe patterns

Head Start Framework:

P-ATL 6: Child maintains focus and sustains attention with minimal adult support

P-ATL 9: Child demonstrate flexibility in thinking and behavior

P-ATL 11: Child shows interest in and curiosity about the world around them

P-LC 2: Child understands and responds to increasingly complex communication and language from others

P-SCI 1: Child observes and describes observable phenomena (objects, materials, organisms, and events)

P-SCI 2: Child engages in scientific talk

P-SCI 4: Child asks a question, gathers information, and makes predictions

P-SCI 5: Child plans and conducts investigations and experiments

P-SCI 6: Child analyzes results, draws conclusions, and communicates results

Activity 1

How can we fix our classroom?

Approximate time: 20-30 min

Group size: Individual and group work

Materials: items to create problems (excess paper, colored pencils, books, baskets, etc.), engineering design process wheel (created Unit 1), engineering badges

- Teacher introduces activity. There are problems throughout the classroom that the students need to solve using the engineering design process.
- Using the engineering design process wheel (perhaps displayed at the front of the class), students either individually or in groups can work out problems using the problem solving process.
- Problems can be simple and relevant to child's life within the classroom.
- Share experiences in the classroom as a group after all the problems in the classroom are fixed
    - Each child or group can discuss their problem using the EDP, acting as a natural assessment for teachers to gather information
- Problem ideas

  - Overflowing trash can
  - Unorganized colored pencils
  - Not enough room in a bookcase box for all the books
- Goals
  - Students should be more independent in the process
  - Student should be able to successfully use vocabulary when discussing problems and solutions
  - Students should be able to solve every problem in the classroom

Activity 2

Story Time: Identifying the Engineering Design Process

Approximate time: 20 min

Group size: Whole class

Materials: engineering books, chalk/white/paper board to write ideas, engineering badges, engineering design process wheel

- Using any children's books, talk through the characters' problem solving process with students
- Ask students to identify problem(s) presented in books and brainstorm own solutions before seeing what the characters do.
- Write down the different ideas on the board and have class compare the different ideas
- Read about the characters' brainstorming and ask students to identify the differences in their ideas versus the characters'
- Have students identify when the character is testing or improving the solution, and when they are explaining it to friends or to the readers
- Natural assessment can occur based on the discussion during class. If all students are involved, the teacher/teacher assistant can determine how successful the students are with the EDP.

Activity 3

Story Time: Identify the Engineer for the job

Approximate time: 20-30 min

Group: Whole group

Materials: Photographs of different problems (can be found online or drawn), engineering design process wheel, chalk/white/paper board

- Hold up pictures of different problems and discuss what type of engineer would be best for the job and why
- What strengths and knowledge should the engineer have?
- Discuss how the engineer might solve the problem and what each step of the engineering design process would look like
  - Have each student draw pictures of the steps they would take and the engineer that would help fix the problems. This can also act as an assessment to see where children are still having trouble or getting stuck.

Activity 4

Create your own: Engineering Design Process Wheel

Approximate time: 40 minutes

Group: Individual

Materials: arts and crafts (pencils, markers, paper, etc), classroom engineering design process wheel, engineering badges, engineering/problem song (perhaps posted somewhere in the classroom)

- Have children create their own design wheel
- Add pictures to each item in the process and write (teachers can help students who cannot write yet) key vocabulary words that go with each one.
- Allow students to explain their photos in a show and tell experience for the class
- Once every student has gone, have students sing their favorite engineering/problem song that they have learned over the course of the 8 weeks!
- Assessment of the engineering design process wheel allows teachers to know that their students fully understand each step and can apply it to different problems

For the classroom:

- Take photos of each child while wearing their engineering badge and make a bulletin board that says “We are all Engineers!”
- Each child can say their favorite thing about engineering and have it written underneath their picture!
- Post the vocabulary words around the room so children can see and learn to recognize the words- include a photo to help those students who cannot read yet.

Family connections

- Ask families to do the same story time activities with their children when at home so they can learn to identify different problems in different scenarios
- Ask families to discuss friends/family members who may be engineers and talk about what they do every day

- Children can illustrate a problem they solved at home and bring in pictures to do a show and tell in school

Curriculum will be:

1. Developmentally appropriate
    a. Fits age level and developmental needs to child
    b. Not too advanced
2. Aligned with national and state STEM standards (Head Start and NGSS)
    a. Fits into Head start system and encourages new science standards in the classroom
3. Aligned with best practices of early childhood & STEM education
    a. Ability to explore on their own
    b. Individual and group work
4. Culturally responsive and builds on children's real-life experiences
    a. Empowers diversity in engineering and encourages anyone to continue pursuing engineering
5. Project-based, designed as integration of STEM practices with literacy
    a. Problem-solving method within different arenas
6. Include embedded, authentic assessment
    a. Assessment is key to investigating success of the program
7. Easy to use by early childhood teachers with no prior STEM background
    a. Professional development that allows teachers to feel comfortable with the material, also usable by teachers that may have less experience with STEM

Appendix II: Data

Appendix IIA: Means and Standard Deviations

Table 13: Percentage of Teachers that responded “Often” and “Very Often” to STEM instruction strategies

“STEM Instruction” Items	Responses for “Often” or “Very Often”	Item Mean (Std. Dev)
Develop problem-solving skills	86%	4.24 (.69)
Work in small groups	91%	**4.45** (.67)
Make predictions that can be tested	75%	3.94 (.66)
Make careful observations or measurements	57%	3.63 (.83)
Use tools to gather data	66%	3.78 (.83)
Recognize patterns in data	38%	3.41 (.79)
Create reasonable explanations of results of experiment or investigation	50%	3.56 (.79)
Choose appropriate methods to express results	44%	3.52 (1)
Complete activities in a real-world context/with a context relevant to children’s own lives	70%	3.86 (.75)
Engage in conversations that are focused on the content of a lesson	89%	4.25 (.64)
Analyze information and solve problems on a complex and thought-based level	47%	3.52 (.82)
Apply math concepts and skills to solve real-world problems/problems relevant to children’s own lives	56%	3.63 (.83)
Critique the way another person arrives at a judgment about something	20%	**2.70** (1.2)
Learn about careers related to the instructional content	42%	3.29 (.93)

Table 14. Percentage of Teachers that responded “Often” or “Very Often” to STEM Engagement

STEM Engagement	Percentage who answered “Often” or “Very Often”	Item Mean
Ask questions about things in the natural world they see around them	95%	**4.45** (.59)
Design things during a lesson	50%	3.63 (.93)
Plan investigations	67%	3.77 (.96)
Carry out investigations	76%	4.03 (.76)

Come up with explanations about why things might happen or why things did happen in a particular way	75%	4.09 (.81)
Change explanations based on new information	81%	3.78 (.86)
Talk with you or other educators about investigations	59%	3.7 (.83)
Talk and collaborate with their peers to solve problems	70%	3.83 (.81)
Apply their past experiences to new situations or investigations	78%	3.95 (.72)
Describe real world problems/problems relevant to children's own lives	75%	3.92 (.74)
Brainstorm/seek multiple solutions to a problem	66%	3.86 (.85)
Come up with solutions to real world problems/problems relevant to children's own lives	72%	3.91 (.90)
Use a variety of ways to represent (model) a solution or idea	58%	3.66 (.93)
Use models to test explanations	53%	**3.58** (1.04)

Table 15. Percentage of Teachers that responded "Agree" or "Strongly Agree" to STEM Teaching Outcome Expectancy Beliefs

STOES Instrument	Percentage of teachers who answered "Agree" or "Strongly Agree"	Item Mean
When a child does better than usual in STEM, it is often because the educator exerted a little extra effort.	55%	3.55 (.85)
The inadequacy of a child's STEM background can be overcome by good teaching.	84%	**3.89** (.69)
When a child's learning in STEM is greater than expected, it is most often due to their educator having found a more effective teaching approach.	58%	3.64 (.70)
The educator is generally responsible for childrens' learning in STEM.	52%	3.50 (.78)
If childrens' learning in STEM is less than expected, it is most likely due to ineffective STEM teaching.	24%	**2.98** (.79)
Children's learning in STEM is directly related to their educator's effectiveness in STEM teaching.	47%	3.34 (.78)
When a low achieving child progresses more than expected in STEM, it is usually due to extra attention given by the educator.	52%	3.42 (.77)
If parents comment that their child is showing more interest in STEM at school, it is probably due to the performance of the child's educator.	55%	3.48 (.73)
Minimal child learning in STEM can generally be attributed to their educators.	33%	3.16 (.78)

Table 16. Percentage of Teachers that responded “Agree” or “Strongly Agree” to Personal Engineering Teaching Expectancy and Beliefs Part 1

PETEB Instrument Part 1	Percentage of teachers who answered “Agree” or “Strongly Agree”	Item Mean (Std. Dev)
I am continually improving my engineering teaching practice	82%	**3.79** (.69)
Given a choice, I would invite a colleague to evaluate my engineering teaching	74%	3.68 (.79)
When a child has difficulty understanding an engineering related concept, I am confident that I know how to help the child understand it better	38%	**3.18** (.76)
When teaching engineering, I am confident enough to welcome childrens’ questions	74%	3.71 (.87)

Table 17. Percentage of Teachers that responded “Agree” or “Strongly Agree” to Personal Engineering Teaching Efficacy and Beliefs Instrument Part 2

PETEB Instrument Part 2	Percentage of teachers who answered “Agree” or “Strongly Agree”	Item Mean (Std. Dev)
I know the steps necessary to teach engineering effectively	19%	**2.75** (.80)
I am confident that I can explain to children why engineering experiments work	39%	3.14 (.85)
I am confident that I can teach engineering effectively	45%	3.23 (.85)
I wonder if I have the necessary skills to teach engineering	48%	**3.27** (.88)
I understand engineering concepts well enough to be effective in teaching engineering	23%	2.89 (.80)
I am confident that I can answer childrens’ engineering questions	31%	2.97 (.85)
I know what to do to increase childrens’ interest in engineering.	38%	3.16 (.80)

Table 18. Percentage of Teachers that responded "Agree" or "Strongly Agree" to Teacher Multicultural Attitude Survey

Teacher Multicultural Attitude Survey Instrument	Percentage of teachers who answered "Agree" or "Strongly Agree"	Item Mean (Std. Dev)
I find teaching a culturally diverse group of children rewarding	94%	**4.56** (.61)
Teaching methods need to be adapted to meet the needs of a culturally diverse group of children	88%	4.39 (.70)
Sometimes I think that there is too much emphasis placed on multicultural awareness and training for educators	11%	2.31 (.94)
Educators have the responsibility to be aware of their childrens' cultural backgrounds	89%	4.25 (.64)
I frequently invite extended family members (e.g. cousins, grandparents, godparents, etc.) to attend parent-teacher conferences	50%	3.33 (1.2)
It is not the educator's responsibility to encourage pride in one's culture	9%	2.19 (1.0)
As classrooms become more culturally diverse, the educator's job becomes increasingly challenging	44%	3.22 (1.1)
I believe that the educator's role needs to be redefined to address the needs of children from culturally diverse backgrounds	50%	3.47 (.89)
When dealing with bilingual children, communication styles often are interpreted as behavioral problems	55%	3.41 (1.0)
As classrooms become more culturally diverse, the educator's job becomes increasingly rewarding	66%	3.88 (.95)
I can learn a great deal from children with culturally different backgrounds	97%	4.48 (.56)
Multicultural training for educators is not necessary	5%	1.86 (.76)
To be an effective educator, one needs to be aware of cultural differences present in the classroom.	94%	4.33 (.65)
Multicultural awareness training can help me work more effectively with a diverse population of children.	86%	4.21 (.72)
Children should learn to communicate in English only.	8%	1.98 (.96)
Today's curriculum gives undue importance to multiculturalism and diversity.	22%	2.70 (1.2)
I am aware of the diversity of cultural backgrounds in my classroom.	95%	4.46 (.64)
Regardless of the makeup of my class, it is important for children to be aware of multicultural diversity.	95%	4.29 (.61)
Being multiculturally aware is not relevant for what I teach.	3%	1.68 (.74)
Teaching children about cultural diversity will only create conflict in the classroom.	3%	**1.60** (.80)

Table 19. Percentage of Teachers that responded “High Priority” or “Essential” to Professional Development Needs

Professional Development Needs	Percentage of teachers who answered “High Priority” or “Essential”	Item Mean (Std. Dev)
Information about how to teach engineering to a diverse group of pre-K children	69%	3.97 (.85)
Classroom management	63%	**4.30** (1.2)
Communicating with families and caregivers about how to support children's engineering learning at home	74%	3.94 (.77)
How to plan engineering lessons for pre-K children	73%	3.97 (.76)
Background knowledge about what engineering is	63%	3.68 (.90)
Information about how to teach engineering to pre-K children, in general	70%	3.98 (.94)
How to create meaningful activities to use in my pre-K classroom	84%	4.27 (.77)
How to get engineers or engineering role models to visit my classroom	73%	3.87 (.86)
How to engage pre-K children in engineering lessons	81%	4.06 (.80)
How to make engineering concepts understandable to pre-K children	81%	4.08 (.73)
Background knowledge about what STEM is	57%	3.78 (1.0)
Background knowledge about the relationship between engineering and STEM	62%	**3.67** (.87)

Table 20. Percentage of Teachers that responded “67%-99%” or “100%” to Classroom Breakdown.

Classroom Breakdown Instrument	Percentage of teachers who answered “67%-99%” or “100%”	Item Mean (Std. Dev)
Children who are ethnic minorities	73%	3.77 (.61)
Children whose first language is not English	41%	3.25 (.76)
Children with specialized learning needs	2%	2.05 (.68)
Children from low-income families	92%	**4.55** (.73)
Children born outside of the U.S.	5%	2.24 (.84)
Gifted Children	3%	**1.64** (.78)

Appendix IIB: Item-Total Correlations

Table 21. Item-Total Correlations for STEM Instruction Instrument*

"STEM Instruction" Items	I-T Correlation
Develop problem-solving skills	0.50
Work in small groups	0.57
Make predictions that can be tested	0.63
Make careful observations or measurements	0.72
Use tools to gather data	0.73
Recognize patterns in data	0.72
Create reasonable explanations of results of experiment or investigation	0.79
Choose appropriate methods to express results	0.74
Complete activities in a real-world context/with a context relevant to children's own lives	0.67
Engage in conversations that are focused on the content of a lesson	0.54
Analyze information and solve problems on a complex and thought-based level	0.77
Apply math concepts and skills to solve real-world problems/problems relevant to children's own lives	0.73
Critique the way another person arrives at a judgment about something	0.66
Learn about careers related to the instructional content	0.76

*all items were statistically significant, $p<0.001$

Table 22. Item-Total Correlations for STEM Engagement in the Classroom Instrument*

STEM Engagement	I-T Correlation
Ask questions about things in the natural world they see around them	0.62
Design things during a lesson	0.81
Plan investigations	0.81
Carry out investigations	0.72
Come up with explanations about why things might happen or why things did happen in a particular way	0.78
Change explanations based on new information	0.75
Talk with you or other educators about investigations	0.71

Talk and collaborate with their peers to solve problems	0.75
Apply their past experiences to new situations or investigations	0.73
Describe real world problems/problems relevant to children's own lives	0.68
Brainstorm/seek multiple solutions to a problem	0.84
Come up with solutions to real world problems/problems relevant to children's own lives	0.82
Use a variety of ways to represent (model) a solution or idea	0.84
Use models to test explanations	0.86

*all items were statistically significant, $p<0.001$

Table 23. Item-Total Correlation for STEM Teaching Outcomes Expectancy Beliefs Instrument*

STOES Instrument	I-T Correlation
When a child does better than usual in STEM, it is often because the educator exerted a little extra effort.	0.74
The inadequacy of a child's STEM background can be overcome by good teaching.	0.35
When a child's learning in STEM is greater than expected, it is most often due to their educator having found a more effective teaching approach.	0.60
The educator is generally responsible for childrens' learning in STEM.	0.74
If childrens' learning in STEM is less than expected, it is most likely due to ineffective STEM teaching.	0.47
Children's learning in STEM is directly related to their educator's effectiveness in STEM teaching.	0.73
When a low achieving child progresses more than expected in STEM, it is usually due to extra attention given by the educator.	0.73
If parents comment that their child is showing more interest in STEM at school, it is probably due to the performance of the child's educator.	0.64
Minimal child learning in STEM can generally be attributed to their educators.	0.63

*all items were statistically significant, $p<0.001$

Table 24. Item-Total Correlation for Personal Engineering Teaching Efficacy and Beliefs Instrument*

PETEB Instrument Part 1	I-T Correlation
I am continually improving my engineering teaching practice	0.73
Given a choice, I would invite a colleague to evaluate my engineering teaching	0.58
When a child has difficulty understanding an engineering related concept, I am confident that I know how to help the child understand it better	0.57
When teaching engineering, I am confident enough to welcome childrens' questions	0.81

*all items were statistically significant, $p<0.001$

Table 25. Item-Total Correlation for Personal Engineering Teaching Efficacy and Beliefs Instrument*

PETEB Instrument Part 2	I-T Correlation
I know the steps necessary to teach engineering effectively	0.76
I am confident that I can explain to children why engineering experiments work	0.86
I am confident that I can teach engineering effectively	0.80
I wonder if I have the necessary skills to teach engineering	0.03
I understand engineering concepts well enough to be effective in teaching engineering	0.82
I am confident that I can answer childrens' engineering questions	0.82
I know what to do to increase childrens' interest in engineering.	0.75

*all items were statistically significant, $p<0.001$

Table 26. Item-Total Correlation for Teacher Multicultural Attitudes Scale*

Teacher Multicultural Attitude Survey Instrument	I-T Correlation
I find teaching a culturally diverse group of children rewarding	0.43*
Teaching methods need to be adapted to meet the needs of a culturally diverse group of children	0.46*
Sometimes I think that there is too much emphasis placed on multicultural awareness and training for educators	**0.70***
Educators have the responsibility to be aware of their childrens' cultural backgrounds	0.67*
I frequently invite extended family members (e.g. cousins, grandparents, godparents, etc.) to attend parent-teacher conferences	0.37*
It is not the educator's responsibility to encourage pride in one's culture	**0.49***
As classrooms become more culturally diverse, the educator's job becomes increasingly challenging	0.13
I believe that the educator's role needs to be redefined to address the needs of children from culturally diverse backgrounds	0.55*
When dealing with bilingual children, communication styles often are interpreted as behavioral problems	0.27*
As classrooms become more culturally diverse, the educator's job becomes increasingly rewarding	0.43*
I can learn a great deal from children with culturally different backgrounds	0.60*
Multicultural training for educators is not necessary	**0.62***
To be an effective educator, one needs to be aware of cultural differences present in the classroom.	0.65*
Multicultural awareness training can help me work more effectively with a diverse population of children.	0.68*
Children should learn to communicate in English only.	**0.58***
Today's curriculum gives undue importance to multiculturalism and diversity.	**0.28***
I am aware of the diversity of cultural backgrounds in my classroom.	0.60*
Regardless of the makeup of my class, it is important for children to be aware of multicultural diversity.	0.70*
Being multiculturally aware is not relevant for what I teach.	**0.63***
Teaching children about cultural diversity will only create conflict in the classroom.	**0.48***

*, statistically significant, bolded correlations are reverse scored

Table 27. Item-Total Correlation for Professional Development Needs Instrument

Professional Development Needs	I-T Correlation
Information about how to teach engineering to a diverse group of pre-K children	0.85
Classroom management	0.43
Communicating with families and caregivers about how to support children's engineering learning at home	0.59
How to plan engineering lessons for pre-K children	0.73
Background knowledge about what engineering is	0.80
Information about how to teach engineering to pre-K children, in general	0.86
How to create meaningful activities to use in my pre-K classroom	0.68
How to get engineers or engineering role models to visit my classroom	0.62
How to engage pre-K children in engineering lessons	0.82
How to make engineering concepts understandable to pre-K children	0.79
Background knowledge about what STEM is	0.58
Background knowledge about the relationship between engineering and STEM	0.77

*all items were statistically significant, $p<0.001$

Appendix IIC: Reliabilities (Cronbach's Alpha) and Means

Table 28. Reliabilities and Means for each instrument.

Name of Instrument	Stem Instruction	STEM Engagement in the Classroom	STEM Teaching Outcomes Expectancy Beliefs	Personal Engineering Teaching Efficacy and Beliefs (1)	Personal Engineering Teaching Efficacy and Beliefs (2)	Teacher Multicultural Attitude Scale	Perceived Professional Development Needs
N (number of items)	14	14	9	4	7	20	12
α (Cronbach's alpha)	0.91	0.94	0.81	0.60	0.81	0.82	0.89
Mean (Std. Dev)	3.70 (0.56)	3.87 (0.65)	3.44 (0.48)	3.59 (0.52)	3.06 (0.57)	3.99 (0.41)	3.96 (0.61)

Appendix III: Figures

Figure 1. Percentage of teachers who agreed or strongly agreed that inadequate STEM knowledge could be overcome by good teaching.

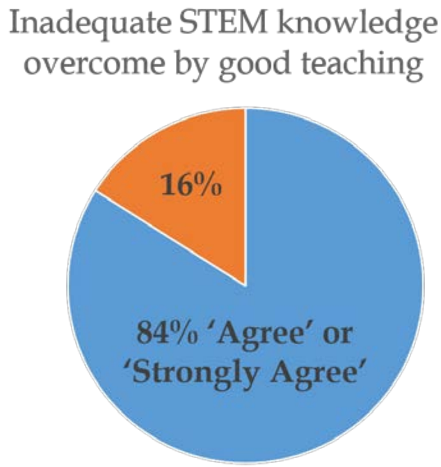


Figure 2. Percentage of teachers who found teaching multicultural students rewarding.

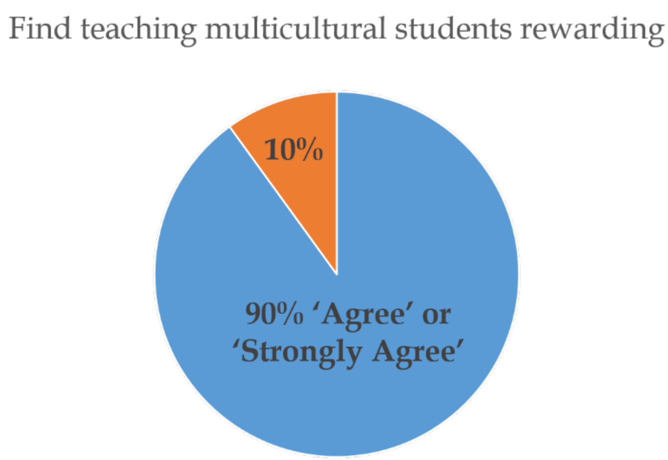


Figure 3. Gender in the Draw an Engineer at Work.

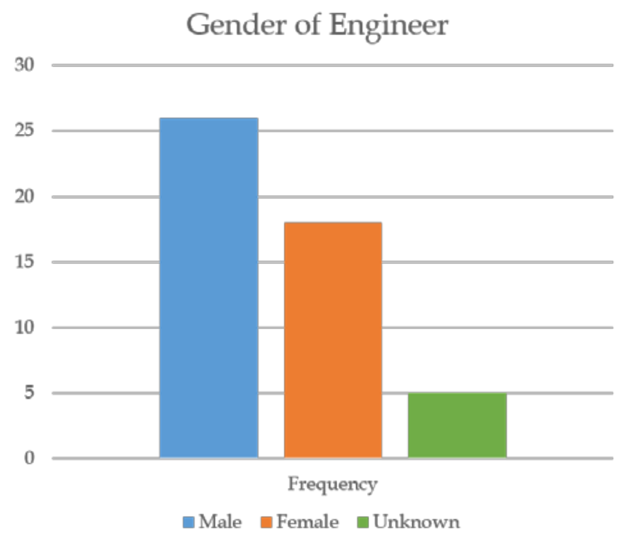


Figure 4. Age in the Draw an Engineer at Work Activity.

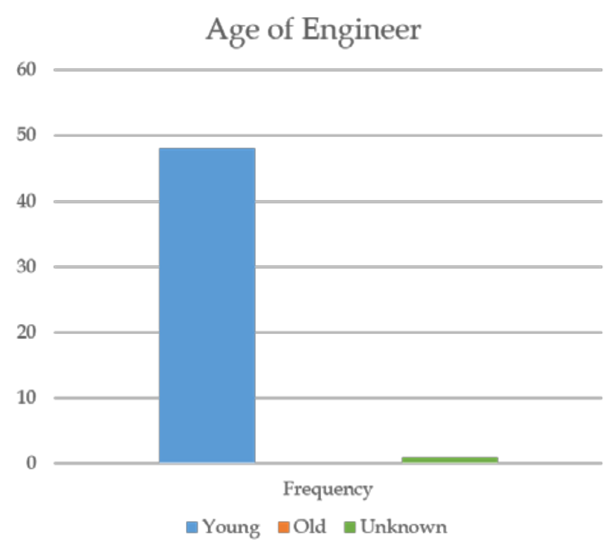


Figure 5. Ability in the Draw an Engineer at Work Activity.

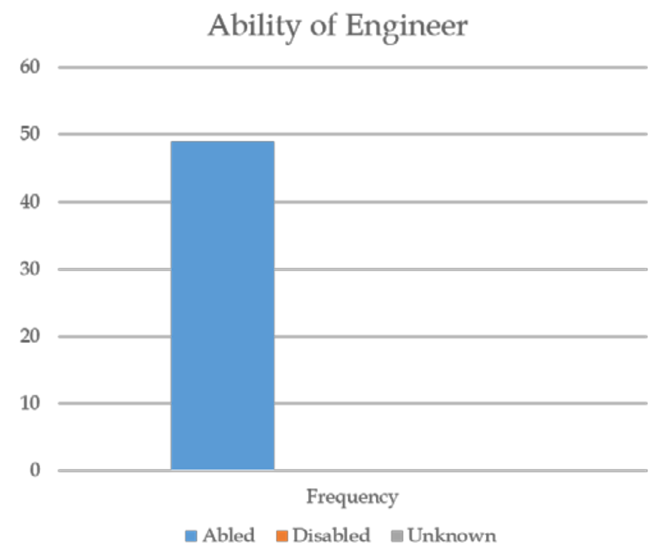


Figure 6. Occupation in the Draw an Engineer at Work Activity.

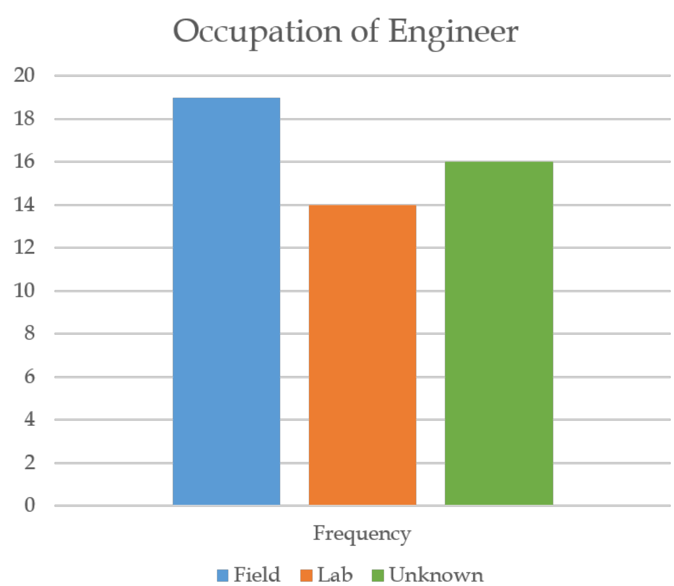


Figure 7. Example Drawings from Draw an Engineer at Work Activity.