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Original Paper

Academic Collaborative Efforts to Promote STEM Equity in High Needs Schools

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Abstract

America is at risk of facing a shortage of workers in STEM fields in the near future because lack of interest by its youth. It is well known that providing early exposure for P-12 students to engaging science, technology, engineering, and math (STEM) experiences can lead to lifelong learning and positively impact future career decisions. This manuscript describes one university's collective efforts to bring equity to STEM education for an urban high needs school district in the northeastern part of the United States through various STEM initiatives over a five-year period. Through multiple projects and initiatives targeting both P-12 students and their teachers, descriptive results revealed a positive impact while pinpointing areas that still require attention. P-12 students indicated an increase in STEM knowledge and an increased interest in STEM careers following exposure to various STEM lessons and interactive experiences. P-12 teachers specified that Professional Development (PD) they received from university faculty as well as engaging in STEM experiences with their students enhanced their confidence in their ability to incorporate STEM lessons within their classrooms. An urban partner administrator viewed these various STEM initiatives as vital in their quest to bring equity for STEM education to their diverse student population.

Keywords

STEM initiatives, STEM education, high needs schools, urban education, STEM equity

1. Introduction

Over the past decade, much has changed in the United States regarding STEM (Science, Technology, Engineering, and Mathematics) education. In 2010, the President's Council of Advisors on Science and Technology report stated that the United States fell behind other developed nations in STEM education in K-12 schools with American students underperforming. Concurrently, the National Center for Education Statistics (2009) and the National Science Board (2010) also reported on how European and Asian global competitors in developed countries were surpassing the American workforce in STEM careers. The STEM education fire was fueled in 2009 by President Obama launching the “Educate to Innovate” campaign (Obama, 2013) to stimulate American K-12 students’ performance in math and science. This article describes multiple strategies that a small urban university in the northeast strategically implemented in STEM and STEAM (Science, Technology, Engineering, Arts, and Mathematics) initiatives that targeted high-needs P-12 students as well as provided Professional Development (PD) for their teachers in efforts to stimulate STEM education in their small corner of America. Results herein highlight both successes and struggles in P-12 STEM education efforts and present recommendations for alleviating some of the burdens.

2. Literature Review

2.1 Importance of P-12 STEM Education

A great emphasis has been placed on increasing STEM education and the production of STEM workers in the United States (Obama 2016). It has been stated that the future of the American economy rests largely in the ability of our country to keep up with the demand for STEM professionals (Al Salami et al., 2017). Even with the increased attention on STEM over the past decade, a projected shortage remains for STEM workers to fill the job demands of the future (National Center for Science and Engineering Statistics [NCSES], 2017; National Science Board, 2018). In the digital world that we have become, the near future forecasts the need for highly trained professional STEM workers, particularly in math and computer science (Fees et al., 2018). As our global society continues to advance technologically, consumer demands increase the growing need for STEM professionals in these highly trained areas. Fees et al. (2018) also state, that although many high school age students enjoy technology and computers, there tends to be a lack of interest in these same careers stating, “there are more computer science related jobs than there are graduates qualified to fill these positions” (p. 1). The need for these highly trained STEM professionals is well known and acknowledged. However, an important question remains: What initiatives are undertaken in American P-12 schools to address these deficits? While much progress has been made over the past decade to reach and motivate American school children in the areas of STEM, more work remains to fill the gaps.

This attention to STEM has changed instruction in P-12 schools, although not equally across all schools. Schools have begun to create unofficial academic and curricular pipelines to encourage students to pursue STEM disciplines (Lyon et al., 2012; Ralston et al., 2013). This pipeline begins with more STEM course offerings to students in high schools, although the challenge remains to find teachers qualified to teach these STEM courses as many professionals choose fields in industry over education (Fees et al., 2018). In order to prepare students for advanced math, science, and technology courses in high school, students also need to take advanced courses in middle school. The pipeline extends to the elementary and early childhood levels as well. The need exists to expose young children to STEM in order to spark their interest so that they will have the desire during their middle school and high school years to engage in and perform well in math and science. This early exposure to STEM for young children helps to develop and prepare their 21st Century skill set (DeJarnette, 2018a). Within the past decade, this new awareness for STEM education has led many states to adopt new K-12 standards such as the Common Core State Standards (CCSS) in reading and math, and the Next Generation Science Standards (NCSS). These standards are tied to 21st Century competencies (Pearson, 2017).

2.2 Struggles with K-12 STEM Implementation

While there is an increased awareness regarding the need for enhanced STEM education and workforce in America, there are numerous challenges for P-12 schools in meeting those needs. According to Proudfoot et al. (2018), “Among the challenges of fully teaching STEM are limitations in teacher education, efficacy, and skill in STEM topics” (p. 20). As teachers are the driving force in any educational setting, they also hold the working keys to enhance student learning. One of the challenges that came with the introduction of STEM and the NGSS framework was the integrated curriculum of science, technology, engineering, and mathematics, coupled with teachers’ lack of training in disciplines outside of their certification area (Ring-Whalen et al., 2018). As a result, professional development is necessary in order to assist teachers with the nature of integrated curricular models and connected subjects that they are less familiar with, such as engineering (Neebel, 2015). Pearson (2017) states that, “One limiting factor to teacher effectiveness is teachers’ content knowledge in the subjects being taught” (p. 225). In order to be truly effective in teaching the integrated STEM curriculum, teachers need support in building their STEM content knowledge, teaching practices, and resources.

Guiterrez (2016) states, “We must have science teachers who are not only on the cutting edge of content and pedagogy, but also passionate and dedicated to engaging all children, regardless of their ZIP codes”. Teachers of STEM need to be passionate about the content they are teaching in order to inspire kids to pursue STEM career paths. According to the President’s Council of Advisors on Science and Technology 2010, “The problem is not just a lack of proficiency, there is also a lack of interest in STEM fields among many students” (Prepare & Inspire, 2010). Young students often fear math and science because of a personal struggle with the content or the apathetic approach to instruction from their teachers. Many teachers lack pedagogical skills to teaching STEM which results in either shying away from it or heavily relying on textbooks to teach the content. When teachers lack confidence in teaching the integrated curriculum, they can impart to their students their same feelings of negativity, fear, lack of confidence, and apathy for STEM subjects. In order for students’ perceptions and interests towards STEM to be sparked, teachers need professional development to help them build self-efficacy, positive attitudes, collaborative environments with peers, and the ability to develop engaging instructional strategies (Al Salami et al., 2017; Knight et al., 2015). DeJarnette (2018b) previously stated: “If children do not receive exposure to engaging activities in STEM during their K-12 years, they are much less likely to pursue it during their undergraduate university years. The lack of science exposure for elementary students can be detrimental to building positive attitudes as well as their own perceived abilities (self-efficacy)” (p. 107).

An additional road block that often inhibits the development of STEM education in American schools is the lack of funding. Budget cuts in American education over the past several years have greatly diminished the enhancement of STEM education in P-12 schools. Financial resources are needed in order to successfully implement the integrated STEM curriculum in schools through teacher training, classroom materials, teacher collaborative planning time and the availability of technology (Pearson, 2017).

2.3 The “E” in STEM

Common Problem-Based-Learning (PBL) activities in STEM classrooms today reflect the cognitive thought processes of engineers and are referred to as Engineering Design Challenges (Grubbs et al., 2018; Alemdar et al., 2018). Design challenge integrated learning experiences are now the preferred method of teaching STEM as these problem-solving practices are critical features of engineering education (Bartholomew et al., 2018). Thornburg (2009) believes that engineering is the glue that holds STEM together. Oftentimes in schools, an attempt to focus on STEM can sometimes lead to “siloing” science and math as separate entities. It is the engineering piece that often brings everything together making STEM truly interdisciplinary. Engineering design challenges require the integration of the STEM subjects, and now teachers oftentimes include art in the design concepts and refer to it as “STEAM”.

The engineering piece however is what teachers struggle with the most when implementing STEM into their curriculum (Wang & Nam, 2015). Previously, engineering education was not part of preservice teacher training at any level, however, now that it is part of the NGSS framework, it has become more commonplace, but much work still needs to be done. The NGSS framework focuses on three core ideas within the engineering component for K-12 students which are: defining and delimiting engineering problems, designing solutions to engineering problems, and optimizing the design solution (NGSS Lead States, 2013). These components of the engineering design challenge at the kindergarten level is very similar to the components at the high school level. The engineering design process of Ask, Imagine, Plan, Create, and Improve sets the stage for an engineering design challenge that is aligned to the NGSS components (Jackson et al., 2011). What makes the engineering design challenge learning segment unique is that it teaches students to work within certain identified constraints and limitations just as engineers do. These constraints could be materials, budget, or even time. These processes give K-12 students the opportunity to innovate and to operate within the realm of STEM in order to understand real world problem solving. Alemdar et al. (2018) share their hypotheses that “applied engineering experiences that require active engagement with foundational mathematics and science practices will lead to increased student engagement, self-efficacy, persistence, and academic achievement in STEM" (p. 364).

2.4 Urban Education and STEM

It is no secret that not only does the United States struggle to keep up with the demand for skilled STEM workers, but there is an underrepresentation of racial and ethnic minorities as well as females in STEM fields (NCSES, 2017). Despite the development of many programs and initiatives to increase STEM education, underrepresented minorities, constituting 40% of the U.S. population, remain alarmingly underserved in STEM fields (NACME, 2017; Prepare and Inspire, 2010). It has been determined that STEM education can bring social equity by providing engaging experiences for all students to increase students' competencies in math and science (Peters, 2018). However, even with the best intentions at hand, school districts that serve low-income families receive fewer STEM initiatives than wealthier districts (Khan & Rodrigues, 2017). Gutierrez (2016) writes "And yet, in spite of all this attention [to STEM], we continue to struggle when it comes to getting excellent, well-trained science teachers in front of all children—not just those who live in our wealthiest districts or attend private schools". Quality STEM instruction embodies all students with an emphasis on problem solving and engagement with the integrated subjects. Providing quality STEM instruction for all students enhances STEM literacy through increased academic achievement, collaboration, and critical thinking resulting in more inclusive classrooms (Powell et al., 2018; Alemdar et al., 2018; Fees et al., 2018).

3. STEM Outreach Initiatives

In light of the American struggles to attract and produce quality STEM professionals from our youth, there has been a surge in STEM outreach initiatives across all levels. As mentioned previously, STEM education within the P-12 schools has increased over the past decade in order to create pipelines for students to pursue STEM careers. In addition, there has also been a push for universities, scientists, and corporate America to create STEM outreach initiatives to attract American youth as well. Boone and Marsteller (2011) state that while recruiting STEM professionals and university students to provide engaging STEM outreach activities for young students, they often do not have the training and the skills to reach this population. Other entities have also provided strong STEM and engineering initiatives for youth through after school programs, coding robotics competitions, and mobile laboratories. Robelen (2013) advocates for engineering design activities in schools stating, "A top pitch is the power of the engineering-design process to engage young people and bring math and science concepts to life with practical, real-world applications…" While engineering design challenges provide engaging STEM experiences for P-12 students, its presence is not consistently spread across all schools and levels. Many students go through their entire P-12 years without having experienced a single engineering lesson, even with today's heightened attention to STEM education.

3.1 Teacher Professional Development (PD) in STEM

One goal for university faculty is to provide much needed professional development (PD) for P-12 teachers in local urban centers as well as in high needs schools state-wide. With the state adoption of the NGSS in late November 2015, it was anticipated that PD would be needed for teachers on how to navigate the new standards, integrate the STEM disciplines, and provide instruction in engineering at the various grade levels (NGSS Lead States, 2013). Research has shown that PD can help fill the gaps for teachers regarding content knowledge, teaching strategies, and identifying valuable resources (Nadelson et al., 2013). Engineering education is a new piece of the puzzle within the NGSS framework that requires teachers to implement engineering concepts and practices into the curricula in all grades, from primary grades through high school (NRC, 2012). Engineering education can be intimidating to many teachers, particularly at the elementary level, who feel unprepared to teach the newest STEM concepts represented in the NGSS standards (Goffin & Clegg, 2014; Duncan et al., 2011). Teachers unpreparedness to teach engineering education often negatively impacts their self-efficacy and dispositions towards STEM, which in turn can negatively influence their students (Wang & Nam, 2015). Nugent et al. (2010) report that PD in truly integrated STEM experiences resulted in a positive increase in teachers' self-efficacy and dispositions towards STEM. Providing quality PD for K-12 teachers can therefore serve as a catalyst for improving student learning and achievement in the areas of engineering education and STEM (Thornburg, 2009; DeJarnette, 2012).

3.2 Theoretical Framework

The framework behind the STEM initiatives described herein by a small university in the northeastern part of the United States incorporates both Vygotsky's constructivist learning theory and sociocultural theory, as well as Bandura's social learning theory.

3.2.1 Constructivism

Lev Vygotsky (1978) presented that learning is student-centered and the instructional focus is on students working together to find solutions to problems. The constructivist theory proposes that people learn best by doing, and they actively construct knowledge by interacting with their surroundings, other learners, and facilitators (Schunk, 2016). Vygotsky's sociocultural theory poses that people learn best in a social environment through hands-on activities, where students interact with each other to grapple for solutions to learning challenges. This pedagogical approach to collaborative learning aligns both with the Piagetian constructivism model and the Vygotskian constructivism model (Schunk, 2016).

3.2.2 Social Learning Theory

Albert Bandura (1971) presented that learners develop understanding through interaction with and observation of their environment. Bandura posed that people learn from models where the processes of attention, retention, production, and motivation are involved to produce new behaviors (Schunk, 2016). By working collaboratively with peers and receiving guidance from a facilitator (teacher), this theory posits that students learn through active engagement with a problem.

These theories fully represent the advocacy of engaging, hands-on, collaborative, authentic problem-based learning of truly integrated STEM lessons described in this paper. Not only do P-12 students grow and develop through experiences with such integrated STEM curricula, but thrive and are successful.

4. Methodology

4.1 Demographics and Populations Targeted

The university resides in the northeastern part of the United States and is situated within an urban setting, with both undergraduate and graduate populations in 125 different majors. The university has an estimated 5,000 students enrolled each year. A group of faculty and staff members have collaborated on various STEM outreach projects over the past five years and are represented by the School of Education, School of Engineering, and the School of Arts and Sciences. This university collaborative effort provided STEM outreach to urban high-needs schools where P-12 students are largely minorities and represent underserved populations. The goal was to reach P-12 students through early exposure to STEM content and disciplines with hopes to attract these minority youths to future careers in STEM. Throughout this manuscript, STEM and STEAM are used interchangeably where some projects had a STEM focus without highlighting the arts, but the arts were still present and played an equally important role in design and creativity.

4.1.1 Urban City Demographics

The urban location for this high-needs school district is a city with approximately 150,000 people. The median household income in 2017 was around $45,000 per year, which is well below the state average (City-data, 2020). Ethnicities of the city population included 40% Hispanic, 35% African American, and 19% Caucasian. The crime index of this city is 341.6, which is well above the U.S. average of 274.0. The difficult urban issues which surround this city are similar to other urban centers around the United States with 20.4% of residents living in poverty (City-data, 2020).

4.2 Description of STEM Initiatives and Results

All the studies and projects described below, which include data collection methods from human subjects, were approved by the university’s Institutional Review Board (IRB) and were performed in accordance with the ethical standards of the IRB committee and “with the 1964 Helsinki declaration and its later amendments or comparable ethical standards”. The variety of STEM initiative projects and those impacted by each are described below and listed in Table 1.

Table 1. STEM Projects and Initiatives with the Number of P-12 Students, Teachers, and Administrator Participants

Projects and Initiatives	**P-12 Students**	**P-12 Teachers**	**University Faculty**	**P-12 Administrators**
Preschool STEAM PD	45	50	1	1
STEM PD for K-12 Urban Science Teachers	-	49	4	-
STEAM PD and Push-In Project	~285	15	1	2
Family Engineering Events	~450	25	1	4
Student Spaceflight Experiments Project, 2017	~300	3	1	3
Student Spaceflight Experiments Project, 2018	~400	4	1	4
STEM-on-Wheels Mobile Laboratory	~3,500	200	5	10
University's Engineers Week	~300	2	10	-
Cyber Robotics Coding Competition	126	30	6	-

4.3 Preschool STEAM Professional Development (PD)

This qualitative survey-based research study provided PD for all preschool teachers in the local urban center on the integration of STEAM into their curriculum during the 2015-16 academic year. The preschool teachers received two full days of Professional Development (PD) that were three months apart. These PD workshops involved 50 in-service preschool teachers instructing children ages three to five. Ninety percent of the teachers were female with the majority of them being African-American. Data collection for the study consisted of a pre-survey and a post-survey with a 5-point Likert scale related to their comfort level in teaching STEAM lessons with their preschoolers. Some teacher participants were interviewed and the researcher recorded field observations to round out the methodology for the triangulated data collection as recommended by Fraenkel and Wallen (2003). This research was funded by a university seed grant initiative.

The workshops included an overview of the NGSS, early engineering education, modeled hands-on STEAM lessons incorporating the children's engineering design loop (Jackson et al., 2011), and STEM learning centers. The modeled whole-class STEAM lessons utilized children's literature and everyday recyclable materials. During the final PD workshop, the researcher conducted several random teacher interviews which were recorded to ensure transcription accuracy with member checks as recommended by Fraenkel and Wallen (2003).

The findings of this study revealed that six out of the twelve survey questions indicated a statistically significant positive change from the pre-survey to the post-survey as indicated by the teachers' levels of efficacy in their ability to plan and implement STEAM lessons with their preschool students (DeJarnette, 2018a). Findings also demonstrated an increase in the preschool teachers' levels of self-efficacy in teaching STEAM, as well as an increase in their dispositions towards STEM. It was determined that additional research was needed for determining the rate of implementation of STEAM activities after such PD as many teachers indicated that although they enjoyed and valued the PD, they did not actually implement STEAM activities within their classrooms. Albeit, the two projects described directly below were designed to further probe how PD can be enhanced so that teachers feel more confident and empowered to implement STEM activities in their classrooms.

4.4 STEM PD for K-12 Urban Science Teachers

This qualitative case study was designed to fill the need for PD for urban science teachers in implementing the newly adopted NGSS and engineering education (DeJarnette, McCulloch, Ngoh, & Badara, 2020). The research project was funded by the NASA Connecticut Space Grant Consortium and consisted of a three-day PD workshop that ran consecutively for two summers, 2016 and 2017. The workshops were offered in two large urban centers and served 49 teachers overall, with 26 agreeing to participate in the study. The qualitative data collection methods consisted of focus groups, random teacher interviews, and researcher field observations during the PD workshops regarding the teachers' self-efficacy and dispositions regarding STEM teaching. The researchers served as participant observers (DeWalt & DeWalt, 2011) as they were directly involved in the PD workshops serving as facilitators.

This case study revealed an increase in teachers' self-efficacy and dispositions regarding integrated STEM teaching. The greatest increases as reported by the participants manifested in the area of teacher self-efficacy in their ability to plan and implement STEM lessons as a result of the PD. In addition, teachers also indicated continued challenges to STEM implementation such as lack of funding, limited PD, and limited instructional time. One limitation to this research is that the teachers self-selected themselves for the PD offering, thus indicating a possible pre-disposition toward STEM learning (DeJarnette et al., 2020).

4.5 STEAM PD and Push-In Project

Previous research studies revealed that although PD had a positive effect on teachers' dispositions and self-efficacy towards STEAM teaching, the teachers were still reluctant to fully implement the instruction within their classrooms (DeJarnette, 2018a). In response to this dilemma, a new project was designed whereby in addition to providing PD for the teachers on STEAM, resources were made available through a grant, and instructional modeling was provided by the researcher (pushed-in) within the classrooms to facilitate the STEAM lessons with students. The project was funded by the NASA Connecticut Space Grant Consortium over a two-year academic period from 2016 to 2018. Data collection was similar to the aforementioned project involving pre/post teacher surveys, teacher interviews, and field observations where the researcher was a participant observer. Therefore, the researcher worked with grade level teams in an urban K-8 school to provide PD instruction, resources and the modeling with students of STEAM engineering design lessons that were literature-based. Each STEAM lesson was grade level appropriate, NGSS aligned, initiated through children's literature, and followed the engineering design loop (Jackson et al., 2011).

Results of this project also showed an increase in teachers' self-efficacy and dispositions towards STEAM instruction, but more importantly, many of the teachers that received hands-on PD are now regularly implementing STEM lessons in their classrooms on their own. The school principal recently reported that 70% of teachers from this study are regularly implementing STEAM lessons at least 1-2 times per month.

4.6 Family Engineering Events

According to Jackson et al. (2011), "Family engineering is an informal engineering educational program that actively engages elementary-aged children and their families in fun, hands-on, engineering activities" (p. 1). As such, these family events were organized and facilitated in two area schools. The first event was part of the "push-in" research project described above and was provided for students in grades 3-5 in this urban school in spring 2018. The event drew approximately 100 participants including the students and their families. The second event was offered later that spring in a suburban elementary school for students in grades 4-5 and drew approximately 350 students with their families. During these events, both students and their parents experienced positive and engaging engineering challenges which incorporated their collaboration, creativity, critical thinking, and problem-solving skills.

4.7 Student Spaceflight Experiments Program (SSEP)

Faculty members at the university had the opportunity to facilitate two SSEPs, in 2017 with area urban high school students and in 2018 with undergraduate students. These SSEP projects were funded by grants from the NASA Connecticut Space Grant Consortium, the university, and the supporting high school. The SSEP immerses students and faculty in real science where students work in teams of 3-5 to competitively design science experiments to be conducted in microgravity onboard the International Space Station (ISS) (National Center for Earth and Space Science Education (NCESSE), 2019).

Another focus of the SSEP is to engage younger students in the projects as well. For both years of involvement, a university faculty team member worked with five K-12 schools in the same urban school district where students competitively designed (3.5 x 3.5 inch) mission patches, with two winning patches flown onboard the ISS along with the selected SSEP microgravity experiment. Each year, over 300 K-12 students designed mission patches for the competition, with the university faculty and community partners judging and awarding the two patches selected for actual space flight. These patches were later framed and returned to the schools with an official "*Flown in Space*" certificate. The SSEP experience had a phenomenal impact on a large number of K-16 students providing authentic real world STEM exposure.

4.8 STEM-on-Wheels Mobile Laboratory Project

The *STEM-on-Wheels* mobile laboratory project is an ongoing multi-grant-funded collaborative project between the university and a local science museum. The team received a donated city bus that was then modified and retrofitted to resemble a science laboratory. The ultimate goals of this project are to provide exposure to rich technology and hands-on lessons that are NGSS aligned for K-12 grade students in this large high-needs urban district. The team designed inquiry-based STEM lessons to be conducted in and around the *STEM-on-Wheels* mobile laboratory. Facilitation of lesson instruction is provided by university engineering, science, math, and education students. STEM lesson emphasis is on providing engaging STEM technology that urban school children would not otherwise have access to while at the same time support integration of NGSS science content standards.

It was hypothesized that through the provision of resources, hands-on STEM lessons, and unique lesson delivery using the mobile STEM laboratory, there would be an increase in the K-12 students' knowledge, skills, and dispositions regarding STEM content and disciplines. It was also hypothesized that the K-12 classroom teachers would welcome the much-needed incorporation of NGSS-aligned hands-on STEM activities into their curriculum and that they would show an increase in their knowledge, skills, and self-efficacy regarding STEM content and lesson delivery. This would then result in an increase in the rate of implementation of STEM lessons within their classrooms. Data collection for this project included electronic student pre- and post-surveys, teacher pre- and post-surveys, teacher interviews and/or focus groups, and field observations. After utilization of the *STEM-on-Wheels* lessons with their students, survey results shown in Figure 1A reveal a 25% increase in teachers expressing confidence in their ability to incorporate STEM activities for their students and a proportional decrease in their apprehension towards STEM activities in the classroom. Albeit none of teachers felt that they have received adequate training and/or professional development on how to implement integrated STEM instruction with their students. Survey results also indicated an increase in student knowledge and positive dispositions towards STEM. A key finding shown in Figure 1B was that student interest in considering STEM careers when they grew older increased post-exposure to *STEM-on-Wheels* lesson activities.

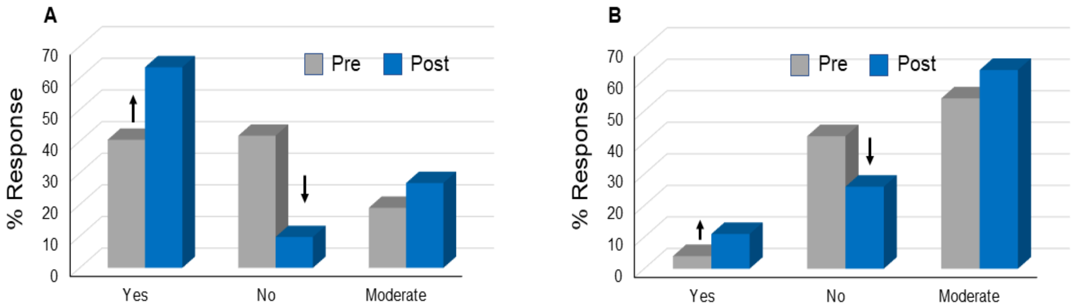

Figure 1. (A) Confidence of P-12 Teachers in their Ability to Incorporate STEM Activities for Students, (B) P-12 Student Interest in Pursuing STEM Careers

4.9 University's Engineers Week

The university's School of Engineering held its first Engineer's Week formal event targeting K-12 students and the urban community in spring 2018, and then again in 2019. This was a collaborative event which involved both undergraduate and graduate engineering students from various student engineering organizations as well as faculty from the School of Engineering and the School of Education. This event targeted K-12 students in the same local urban school district mentioned in earlier initiatives and provided attendees with hands-on engineering activities in an informal exposition-type setting. During this event, students had the opportunity to visit and explore different stations such as a 3-D printer in action, a robot that walks and talks, an interactive digital mirror, make-it and take-it activities, and some brief STEM challenges just to name a few. K-12 students and families enjoyed engaging in conversation with university students and faculty at both events.

4.10 Cyber Robotics Coding Competition (CRCC)

The university's College of Engineering, Business, and Education started hosting the CRCC Connecticut state finals competition in December 2018 and again in 2019. This annual CRCC event involves middle school students in grades 5-8 where they have an opportunity to code a virtual robot on a computer using a Cloud-based platform. This innovative virtual competition brings equity and exposure to STEM and computer programming in a fun environment while introducing students to the college campus. Students work in teams of 1-2 to "complete missions that introduce them to mechanics, physics and programming accompanied by math, science, and engineering principals" (Cyber Robotics Coding Competition, 2019). The university partners with CRCC and awards each first, second and third place finishers with a $1000 college scholarship to the university.

5. Discussion

With an underrepresentation of racial and ethnic minorities in STEM fields in America, urban youth exposure is of utmost importance (NCSES, 2017). Despite great efforts in recent past, school districts that serve low-income families continue to receive fewer STEM initiatives than wealthier districts (Khan & Rodrigues, 2017). These same urban schools struggle to recruit and maintain talented diverse science teachers for all students, thus presenting a gap of quality STEM experiences for urban youth (Gutierrez, 2016). This paper describes numerous STEM outreach efforts that one university has initiated within its local urban school district. Through the initiatives described herein, this university has provided STEM exposure for an estimated 5,400 P-12 students and nearly 200 urban teachers over the past five years. Through the analysis of multiple outcomes from the described initiatives, this manuscript brings to the foreground a critical problem that limits P-12 STEM exposure.

5.1 Impact of Early Exposure of STEM/STEAM Initiatives

The overall data from these early STEM exposures and initiatives indicate positive effects on both students and their teachers' dispositions regarding STEM. Table 1 showed the populations impacted by these STEM initiatives. The largest population receiving exposure were K-12 students at > 80 %. The limited but consistent findings of the various STEM initiatives described here demonstrate a positive impact on all involved in the early exposure experiences. P-12 students indicated positive experiences with the STEM outreach activities and P-12 teachers indicated feeling slightly more confident in their abilities to plan STEM instruction for their students as a result of experiencing the various STEM initiatives. Nevertheless, P-12 teachers continue to display apprehension in the implementation of STEM activities. It is noteworthy that in all events described here that required student and teacher involvement, when P-12 teachers displayed apprehension and disengagement, students displayed similar tendencies. Conversely, when P-12 teachers displayed excitement and were engaged in the activities with their students, outcomes were very positive. Therefore, P-12 teacher's positive disposition towards STEM is concomitant with successful implementation of STEM in the classroom.

5.2 Limitations

Limitations of these STEM initiatives include that the activities were largely conducted within one urban school district in the northeastern part of the United States by one local university's efforts. These limitations evolved due to the nature of working in high-needs schools as cooperation from parents and teachers was inconsistent. These inconsistencies impacted the ability to collect large numbers of consistent data from these schools. It is also noted that data collection was not necessary for every initiative described in this paper. That being said, the purpose of this paper is to describe the STEM outreach initiatives between one university and a local urban school district with an attempt at measuring the impact of early exposure to STEM experiences of P-12 students and their teachers.

6. Conclusion and Recommendations

The development of our own STEM professionals in America translates to motivating our youth to pursue these careers. That motivation comes through positive engaging experiences with science, technology, engineering and math, (STEM). One way to ensure that P-12 students have these positive experiences with STEM is to provide quality pre-service and in-service training for teachers in both pedagogy as well as content knowledge. This is in agreement with the literature as Gutierrez (2016) states, "A high-quality science and engineering education for every child would have a positive impact on our nation, ensuring that all students are prepared to face the science and engineering challenges of the 21st century".

There are many lessons learned during these experiences that will help overcome challenges to STEM implementation in P-12 high needs schools and the broader community. We have identified several criteria that have positively impacted the STEM initiatives described, such as the importance of collaborative hands-on learning for students. When engaging hands-on STEM activities are relevant and connected to their current instruction, it becomes even more impactful. These collaborative authentic STEM learning experiences not only engage today's youth, but also inspires them to achieve a level of STEM knowledge that they never even imagined or conceived for themselves. One goal is to jump-start students' interest in STEM through offering a variety of STEM experiences and exposures through real-world projects. A secondary goal is to positively impact students' dispositions towards STEM through interactions with scientists and other STEM professionals on a personal level. Umali (2020) had a similar goal and stated, "In this way, students can hopefully begin to see STEM as a career path not just limited to those who have already been labeled as "smart"". It is important to foster this type of learning environment, particularly for students in high needs urban settings such as the one described in this paper where more than 90% are students of color and significantly underrepresented in today's STEM career professionals.

With an increased attention to STEM education over the past decade, a projected shortage remains for STEM workers to fill the job demands of the future (National Center for Science and Engineering Statistics [NCSES] 2017; National Science Board 2018). According to Umali (2020), "The United States needs to raise its investment in science, technology, engineering, and math (STEM) to remain globally competitive". One university's response to this alarming statistic was to work together with local school partners to provide various engaging STEM initiatives for students and teachers alike with the goal of bringing equity to STEM education in high needs schools.

6.1 Strategic Plan for Overcoming Limitations in STEM Education

The STEM initiatives presented here have helped to identify several recommendations for stimulating students' interest in STEM disciplines and careers. P-12 school administrative leadership and vision in support of STEM education is crucial to overcoming STEM education barriers in P-12 schools, particularly in urban settings. In this context, supporting the teachers with sustained mentorship is necessary and includes: 1) extensive collaboration with university faculty to help embed STEM curricula where available, 2) application of problem-based learning through authentic experiences where children collaborate in problem-based learning in a social setting, 3) implement and engage in available community STEM activities and experiences to support and extend schools' STEM curricula., and 4) introduce positive experiences that engage older students in real-world STEM applications such as internships at university research labs and/or engineering firms and companies. Through a targeted effort to train and support P-12 teachers, as well as partnering with schools to engage students in high quality STEM experiences, resides the hope to positively influence the outcome of young American STEM professionals in the near future.

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