Building the K-12 Engineering Pipeline: An assessment of where we stand

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Abstract— **This paper is a survey-based assessment of the pre-engineering activities focused on building the engineering pipeline in the Ozarks region of Missouri. We assess the impact of diverse outreach programs including Project Lead the Way, Science Olympiad, the Ozarks sySTEAMic Coalition (O-STEAM) and other Science, Technology, Engineering and Math (STEM) programs/outreach events that have sought to engage the local schools and public at large. Evaluation was based on analysis of survey data collected from middle school and high school students (6-12th graders) in the local schools as well as students currently enrolled in the engineering program at Missouri State University (a cooperative joint program with Missouri University of Science and Technology). The broad and diverse spectrum of students feedback analyzed provided an insight into which activities are effectively building the pipeline and what things we might considering doing differently to strengthen the engineering pipeline. Though this survey is focused on the Springfield Public schools of the Ozarks Missouri region, the methodology and results are replicable to other regions in the US.**

Keywords—K-12, Pre-Engineering, Outreach programs.

I. INTRODUCTION

Most engineering outreach programs recognize the importance of reaching out to K-12 students as early and as often as possible. They all have the common goal of increasing student awareness and interest in Engineering. However, many programs tend to focus on high school students and only reaffirm the students who are already interested in science math and engineering while doing little to spark interest in other students. There is a growing need to increase the attractiveness of engineering studies and promote their awareness to potential students. In recent years, there has been an increasing interest in nurturing a pipeline of motivated students prepared to undertake the rigors of undergraduate engineering studies [1]. There is also an imperative need to attract a diverse pool of students that better reflect the future composition of the engineering workforce. By Engineering

There has been growing concern about the ability to produce and retain science, technology, engineering, and mathematics (STEM) talent in the United States. There is a need to ensure that we are building and strengthening the K12 Engineering pipeline. Pipeline [2] [3] [4] in this context means establishing a conduit or pathway of activities/programs geared towards motivating students all through K12 to choose an engineering (or in general, a STEM related) discipline in college. Some students start undergraduate programs and do not complete their degrees, or they complete their degrees but switch majors. For the most part, students do not declare majors until their sophomore year. Because of this, undergraduate enrollment data for domestic students are not available by field. However, engineering is an exception. Engineering programs generally require students to declare a major or an intent to major in the first year of college, so engineering enrollment data can serve as an early indicator of both future undergraduate engineering degrees and student interest in engineering careers. The Engineering Workforce Commission administers an annual fall survey [5] that tracks enrollment in undergraduate and graduate engineering programs. Undergraduate engineering enrollment was flat in the late 1990s, increased from 2000 to 2003, declined slightly through 2006, rose steadily to a peak of 544,000 in 2012, and declined slightly to 542,000 in 2013. The number of undergraduate engineering students increased by 34% between 2006 and 2013. Full-time freshman enrollment followed a similar pattern, reaching 131,000 in 2012, the highest since 1982, but declining slightly in 2013. These trends correspond with declines in the college-age population through the mid-1990s, particularly the drop in white 20–24-year-olds, who account for the majority of engineering students.

According to a 2014 Missouri Department of Economic Development data [6], STEM occupations are a strong component of Missouri's economy, with higher than average wages, and a broad industrial appeal. They are also projected to be a valuable part of Missouri's employment future. In 2012, STEM occupations accounted for 5.2% of Missouri's total workforce, but the same occupations are projected to comprise 6.2% of the statewide 2012-2022 growth. Missouri's projected growth rate for all STEM occupations from 2012 to 2022 is 10.2%. Compare this to the overall projected rate for the state of 8.6% and it is clear that STEM occupations are an important part of the state's economic growth. It is critical to ensure adequate exposure and preparation of students to STEM disciplines, particularly engineering.

Introducing children to engineering at an early age is very important if we want to begin to increase cohort-size of the next generation of engineering students. It is essential to pique their interest early on diverse possibilities of applying their knowledge about science and math in a way that gets them fascinated with building things, troubleshooting them and taking

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them apart. The question of how we can harness their creative energy and channel it into a choice of a rewarding engineering career is paramount as we look at the K12 student demography. It is therefore imperative that we evaluate and assess how we are reaching out to students in the K12 bracket. How much of engineering related hands-on project learning are indeed a part of their curriculum? How effective are the current outreach activities helping to shape their decision towards engineering? Do these outreach activities each out to minorities and students from diverse background effectively? At what point do they start to develop an interest in Engineering? What factors made the greatest impact on that decision?

In this paper, we collect and analyze data to address these questions. We present a survey-based assessment of the pre-engineering activities focused on building the Engineering pipeline in the Ozarks region of Missouri. We assess the impact of diverse outreach programs including Project Lead the Way, the Ozarks sySTEAMic Coalition (O-STEAM), Science Olympiad, as well as school based programs such as Robotics Club, Technology club, etc. The research model employed in this work departs from the norm that seek to evaluate the effect of pre-engineering activities by focusing on students that are already enrolled in engineering programs. We surveyed both high and middle school students so that we could evaluate their tendency towards engineering based on involvement in pre-engineering programs. We propose that examining responses of these students, who were possibly considering at engineering as a possible course of study, provides a perspective that could lead to early intervention techniques to aid build the engineering pipeline. In addition, we also survey students currently enrolled in the engineering program. In evaluating this diverse spectrum of students, we provide an insight into which activities are effectively building the pipeline and what things we might considering doing differently to strengthen the engineering pipeline. Though this survey is focused on the Ozarks Missouri region, the methodology and results are replicable to other regions in the US.

II. Related Work

There has been a growing interest in understanding student's reasons for studying engineering as a major and how that pipeline can be increased for diversity of reasons [7], [8], [9], [10], [11], [12]. Anderson-Rowland in [8] investigated reasons students choose to study engineering with an aim to understanding engineering students for better recruitment strategies. The paper observed that about 33% of the students surveyed did not decide on Engineering until college. In [9], Sheppard et al. designed a survey to capture student motivations for pursuing engineering: Academic Pathway Learning Engineering Survey (APPLES). It consists of six different motivational components; financial, parental influence, social good, mentor influence, intrinsic (psychological), and intrinsic (behavioral). The psychological category captures ideas related to enjoying or liking engineering, while the behavioral category captures the desire to build fix, or solve. Several authors have examined the impact of independent variables, such as gender on motivation for choosing engineering. Anderson-Rowland in [7] concludes that one of the best ways to influence a student to choose engineering as their major field is for them to have a family member who is or was an engineer. Her study discovered that, generally, students with an engineering family member or friend tend to choose engineering as a field of study earlier compared to students without such role model. To activate recruitment activity effectiveness, the students were asked to rank activities that were influential in their recruitment to study engineering. The most influential activity for underrepresented students was Math/Science Honors summer program for minority students. Watson et al. studied a sample of first year engineering college students to investigate the reasons students chose to become engineers [13]. The most prevalent categories cited by students were the drive to make/build something (behavioral), the desire to be technically challenged, and a general interest in the field (psychological). The least common motivations were mentor influence, previous courses/experiences, and prestige. However, from our findings, mentor influence and previous courses/experiences still play a role.

Some studies have focused on the impact of race and/or gender on entering and persisting in engineering. Despite increase in women's enrollment US colleges and universities, undergraduate women still choose Science, Technical, Engineering and Math (STEM) majors at significantly lower rates than undergraduate men [14]. The difference in their engineering enrollment numbers indicate gender equity issues in STEM disciplines. Maple and Stage [15] concluded that despite gender, students with better academic skills and mathematical reasoning were more likely to persist than those who do not possess these skills. They utilized a longitudinal model of seven exogenous constructs to explore the relationships among background characteristics of students, ability, high school experiences and the choice of major. Jeffers et al. in [16] emphasized the need for infusing concepts of engineering into the K-12 science and math curricula. The most common goal that colleges strive to achieve through investment in K–12 engineering outreach is to increase the pool of potential future engineers [16]. Many of the outreach programs mentioned in their work are not available in the region that we surveyed. In contrast, we are assessing specifically the impact of considering engineering from the student's perspective.

III. Background and Context

The student sample surveyed in this paper is drawn from the city of Springfield, Missouri (SGF) in the Greene County of the Ozarks region. SGF has a total population of 159,498 according to the 2010 Census Report and is the third largest city in the state of Missouri [17]. The population consists of 88.7% White, 4.1% Black, 3.7% Hispanic or Latino, 0.8% Native American, 1.9% Asian, and 1.4% from other races. This study surveyed middle school and high school students from the Springfield Public Schools (SPS) district as well as college students currently enrolled in the Engineering program at Missouri State University (MSU).

A. Springfield Public Schools

Springfield Public Schools is the largest accredited school district in Missouri, with an enrollment of just under 25,000 students, having a staff of more than 3,500, students educated at more than fifty sites, including five comprehensive high

schools, ten middle schools, thirty-seven elementary schools, and several sites for alternative and choice programming. The approval given by the SPS district's analytics, accountability and assessment department restricted our survey sample to only students enrolled in Project Lead the Way (PLTW) classes. (The district thought that we would obtain the largest sample of students interested in engineering from those currently enrolled in the PLTW classes.) SPS is yet to offer PLTW classes to elementary school students. Table 1 and 2 summarizes the demographics of each school and whether or not they were included in this survey report. It also includes the demographics of the sample population surveyed per school. We collected the gender information in our survey but this was not available from the SPS school report [18]. Two of the middle schools (Pershing and Hickory Hills) did not have any PLTW classes. We did not include Wilson's creek since it has only 6th graders. We also obtained no response from Westport Middle school. Our survey assessment included all 5 high schools and 6 middle schools – a total of 11 schools.

B. Engineering program at MSU

The Engineering program at MSU [19] was developed in partnership with Missouri University of Science and Technology (Missouri S&T) Rolla, Missouri in order to address southwest Missouri's need for civil and electrical engineers. The cooperative engineering program is open to students in 16 counties including Greene County (Springfield, Missouri). Since its inception, the program has provided opportunities for students from southwest Missouri to major in engineering and build their careers in the area. MSU continues to offer the Pre-engineering Program to all students, which allows students to complete the first two years of courses on the MSU campus and then transfer to Missouri S&T to complete their Engineering Degree. The program is located on the downtown campus of MSU campus. Students complete all their classes at the MSU site. Students are also allowed to transfer into the Cooperative Engineering Program from partner colleges, such as Ozarks Technical College, if they meet the residency requirement. We had access to all the students currently enrolled in the program. Even though it is a small program, it allowed us to assess students currently pursuing engineering that sprang out of the Springfield, MO area.

C. Project Lead the Way

Project Lead the Way (PLTW) is a school program that provides students with real-world learning and hands-on experience [20]. This makes it a perfect case study for this study as we seek to address the question: How much of engineering related hands-on project learning are indeed a part of their curriculum? The SPS utilizes PLTW as a mechanism to ensure that the students are exposed to hands-on project learning opportunities. Students interested in engineering, biomechanics, aeronautics, biomedical sciences and other applied math and science arenas discover PLTW as an exciting portal into these industries. At the high school level, PLTW offers 3 programs Engineering (Eng.), Biomedical Science (Biomed.) and Computer Science (CS). PLTW Eng. engages students in collaborative, real-world activities like working with a client to design a home, programming electronic devices or robotic arms, or exploring algae as a biofuel source. By pushing themselves to rework and refine their projects, students learn that both failed attempts and perseverance are key to learning and innovation. PLTW CS engages students in real-world activities like creating an online art portal or using automation to process and analyze DNA-sequence data. These projects illustrate how intricately computer science is woven into the society, challenge students to apply computational thinking and logic to solve big problems, and transform students into builders of technology. These programs includes multiple one-year courses. Central, Glendale, and Kickapoo high schools are currently running the Eng. and Biomed. tracks and plan to start the CS component AY 2017-18. Parkview is in its first year of PLTW and only have the CS track. Hillcrest has both Eng. And CS tracks.

PLTW Gateway to Technology (GTT) program is offered to the 6-8 grades (middle school) and seeks to illuminates the range of paths and possibilities students can look forward to in high school and beyond. Students apply knowledge and skill from a variety of disciplines, including all three PLTW pathways, in the program's nine-week units. Tackling challenges like designing tires for a moon rover, cleaning up an oil spill, or solving a medical mystery, students learn to test their limits and connect what they learn in the classroom to making a real-world impact. GTT units empower students to lead their own discovery. The hands-on program boosts classroom engagement and excitement, drives collaboration, and inspires "aha! moments" and deep comprehension. GTT programs use a holistic approach to generate interest. Usually students will start with design and modeling and then proceed in different directions based on interest. All middle schools with the exception of Pershing currently have PLTW programs incorporated into their curriculum. PLTW Launch, designed for the K-5 demography, is not yet available in the Springfield public school district.

D. Outreach Programs

The specific pre-college engineering outreach programs evaluated in this paper are as follows:

a) Science Olympiad: Science Olympiad *[21]*, *[22]* involve students developing and using science skills and scientific reasoning to build new content knowledge and increase their interest in science and engineering. Part of the mission is to improve the quality of science education as well as create a passion for learning science and improve recognition for the outstanding achievements of students and teachers in the STEM area. The Science Olympiad operate under the auspices of national organizations that provide rules and support for national-level competitions. The judges are generally recruited from the local community where the competition is held. Often they are teachers, college/university faculty, physicians, engineers or others with an interest in the program. Their role at the fair is to interview the students at their respective presentations and score the presentations according to a rubric provided by the organizers.

b) Ozarks-STEAM Coalition: The goal of O-steam is to showcase the Ozarks as a national leader in Science,

TABLE I. DEMOGRAPHIC OF SPRINGFIELD PUBLIC HIGH SCHOOLS AND STUDENTS SURVEYED

High School	Total Count	% White ✦	% Black✦	% Hispanic/ Latino✦	% Asian/ Pacific✦	% Others ✦	PLTW Program	Included in Survey	Students Surveyed		
									Total #	%Male	%Female
Central	1,617	70.7 73.6	11.4 6.6	8.3 5.5	6.9 12.1	2.7 2.2	Eng./Biomed.*	Yes	97	52.6	47.4
Glendale	1,364	86.5 86.4	4.9 0	3.4 0	1.5 0	3.7 13.6	Eng./Biomed	Yes	22	95.5	4.5
Hillcrest	1,025	80.7 72.2	10.5 0	3.7 27.8	0.8 0	4.3 0	Eng./CS	Yes	22	77.3	22.7
Kickapoo	1,806	87.1 83.7	4.2 2.0	3.3 12.2	3.2 0	2.2 2.0	Eng./Biomed	Yes	50	96.0	4.0
Parkview	1,367	76.7 85.0	10.5 15.0	6.1 0	2.6 0	4.2 0	CS	Yes	21	90.5	9.5

*: Eng.: Engineering; Biomed.: Biomedical; CS: Computer Science. ✦ Second line indicates demography numbers specifically for students that participated in the survey; SPS did not have overall gender data per school [18].

TABLE II. DEMOGRAPHIC OF SPRINGFIELD PUBLIC MIDDLE SCHOOLS AND STUDENTS SURVEYED

Middle School	Total Count	% White ✦	% Black ✦	% Hispanic/ Latino✦	% Asian/ Pacific✦	% Others ✦	Has PLTW	Included in Survey	Students Surveyed		
									Total #	%Male	%Female
Carver	748	71.0 57.3	11.6 11.2	8.0 14.6	6.0 6.7	3.4 10.1	Yes	Yes	102	52.0	48.0
Central MYSP	131	87.0	3.1	0.8	6.1	3.0	Don't Know	No	N/A	N/A	N/A
Cherokee	800	88.3 72.7	3.8 11.1	3.9 8.1	2.9 6.1	1.1 2.0	Yes	Yes	133	68.1	31.9
Hickory Hills	456	79.6	5.5	7.0	4.2	3.7	No	No	N/A	N/A	N/A
Jarrett	456	78.7 65.4	9.2 11.5	5.5 10.6	3.1 1.0	3.5 11.5	Yes	Yes	128	74.6	25.4
Pershing Middle	708	85.0	5.4	3.4	3.0	3.2	No	No	N/A	N/A	N/A
Pipkin Middle	572	69.9 57.1	17.8 19.6	8.0 12.5	1.2 3.6	3.1 7.1	Yes	Yes	56	50.0	50.0
Pleasant View	368	88.0 75.6	5.2 4.9	2.4 4.9	1.4 0	3.0 14.6	Yes	Yes	43	46.3	53.7
Reed Academy	626	75.2 62.3	14.1 16.4	4.0 8.2	1.9 1.6	4.8 11.5	Yes	Yes	78	44.6	55.4
Westport Middle	465	71.8	18.5	4.3	1.3	4.1	Yes	No	N/A	N/A	N/A
Wilson's Creek (6th Grade)	212	90.6	2.4	2.4	2.8	1.8	Don't Know	No	N/A	N/A	N/A

✦ Second line indicates demography numbers specifically for students that participated in the survey; SPS did not have overall gender data per school [18].

Technology, Engineering, the Arts, and Math (STEAM) businesses and education by documenting, disseminating, and advocating innovative, replicable, and evidence-based strategies that prepare students to thrive in their future education, careers, and adult lives. The program facilitates a collaborative effort in the community to inter-weave the benefits of STEAM along with a strong focus of entrepreneurship in the Ozarks region. Their Maker Faire is a family friendly showcase of invention, creativity, and resourcefulness, along with a celebration of ingenuity and innovation. Their outreach to the Ozark region has resulted in a drive to have maker spaces in Springfield Public Schools.

c) Missouri Society of Professional Engineers (MSPE) Discover Engineering Day: Every year in February the Missouri Society of Professional Engineers (MSPE) hosts a "Discover Engineering" event targeted to students, especially those of elementary-age. The event, hosted currently at MSU, has many fun and exciting activities and demonstrations that illustrate different aspects of engineering. Engineers of all types from the region are a part of this event, to share their love of the design-and-build process and to bring engineering to life for the kids.

d) Discovery center STEM week: Discovery Center of Springfield is an interactive, hands-on science museum committed to inspiring people of all ages with a life-long love of learning and an appreciation for the world and our place in it. The center creates and maintains a fun, inspiring, and interactive educational resource center for students, teachers, and families of the Ozarks. During the STEM week, the center demonstrates and focuses on science and technology exhibits, programs, and collaborative efforts, providing a number of unique, educational opportunities that gives hands-on, interactive, inquiry based learning experiences to help increase

participants' deductive reasoning and critical thinking skills. The center provides scholarships to students who are part of the local school's Free/Reduced Lunch program to help alleviate the cost associated with the programs offered at the center.

e) In-house School Programs: MakerSpace; Robotics club, Technology Student Association, Science Club

Various in-school programs geared toward enhancing interest in technology and engineering exist within the SPS system. Maker spaces in libraries where students can tinker away, putting their creativity to work have been set up in some schools (mainly middle schools) with a district-wide push to make such spaces available in all the school in the SPS district. All PLTW students are encouraged to participate in TSA (Technology Student Association). TSA offers a wide variety of pathways and club members choose what interests they pursue within the club. Activities include: robotics, programming, community service, gaming, design challenges and hands on product problem solving in the materials lab (maker space option). If the students have an interest, they are given the opportunity to pursue that interest.

IV. Research Design and Findings

A. Research Questions & Design

We were interested in measuring student's tendency to choose Engineering as influenced by participation in various pre-engineering activities. Evaluation was based on analysis of survey data obtained from SPS students (7-12th graders) enrolled in the PLTW classes and college students enrolled in the engineering program at MSU. The one-page survey (see Appendix) administered to the SPS students was purposefully designed to be succinct and efficient to collect all the information needed to assess the impact of the outreach programs that they were involved in and yet easy for students to complete in less than 10 minutes. The survey gathered information on gender, race, and the grades of the students. Specific questions included: Has being a part of the PLTW program and skills acquired influenced them to consider studying engineering as a major in college? Which activities in PLTW did they enjoy most? In which of the available outreach engineering programs did they participate? The survey for the college students included questions such as: what subjects sparked their interest in engineering? Who was the biggest influence on their decision to study engineering? What factors makes engineering attractive to them? The results obtained and our analysis are presented in the following section.

B. Results and Findings

The survey was administered to a total of 752 SPS PLTW students (212 high school and 540 middle school) as well as 81 MSU engineering program students. The demographic information of the students survey are listed in Tables 1 and 2. Overall, there were overwhelmingly more males participating in the PLTW program than female with the exception of three middle schools: Pipkin Middle (50% male, 50% female), Pleasant View (46.3% male, 50% female), and Reed Academy (44.6% male, 55.4% female). Given that the overall gender demography information was not available readily for the SPS school district, it was not certain if this mirrored the gender distribution in each school surveyed. The demography of overall SPS student population showed the percentage of enrolled minority and non-white students as indicated in Table 1. However, schools like Glendale and Hilcrest by comparison did not have any students in this category who were a part of the survey. In such instances, follow up questioning with the teachers was needed to validate the results to ensure that the survey results was capturing reliable information. In all cases, the discussions with the teachers reinforced the collected survey response from the students. Concerning participation of students from ethnic minorities in the PLTW program at the high school level, we can observe from Table 1 that Kickapoo and Hillcrest have a high percentage of Hispanic/Latinos in their program compared to the overall distribution. However, some schools have no African-American students in their program. At the middle school level (Table 2), we see a similar trend with participation of Hispanic/Latinos in the PLTW program for all the schools surveyed: the composition is higher compared to the overall distribution. It appears that these schools must be successfully attracting under-represented students from the Hispanic/Latino group.

Table 3 summarizes the participation of the SPS students in the various pre-college engineering programs and outreach events both at the school and off school premises. The Maker Space (M-S) seems to be prevalent in the middle school and effective in providing the opportunity to explore areas of interests and build confidence in the students. This did not seem to be the case for high school students. Although follow-up questions with the high school teachers revealed that there are 'informal' maker spaces in the high schools. They are not officially labeled as such, the students may be unaware of the program. Robotics and TSA activities had a broad appeal across the middle and high school students. For the off school premises programs, Science Olympiad (Sci. Olyp.) and MSPE Discover Eng. Day appeared to be most popular among the students. Discovery Center STEM week (Disc. Ctr. STEM) is a paid program, so financial need may be a factor that could affect the enrollment of the students in it. Figs. 1 and 2 compares the percentage of students interested in engineering/comp. sci. (high or low interest) in correlation to their participation in at least one of the programs compared with those have none.

From Fig. 2, high school students exposed to only PLTW expressed significant low interest in Eng./CS/Eng. as a major. Figs. 1 and 2. also demonstrate that students who are in PLTW classes and involved in other activities were more interested in Engineering. It is important to note that about 30% of the students in PLTW and involved in other outreach programs were not interested in pursuing engineering. A pertinent question that needs answered is how to improve these numbers. There is a higher percentage of students participating in other pre-engineering activities in the middle schools than in high schools as shown in Table 3. This may be a direct result of the fact that most PLTW students in middle school take the classes as mandated by the school (Fig. 3). For the high school student, the choice of taking a PLTW class is majorly driven by an interest to study Eng./Computers/Technology/Hands-on (Fig. 4). This shows that the earlier the students have the opportunity to be involved in pre engineering activities the sooner we can begin to mould their confidence in choosing engineering.

TABLE III. NUMBER OF PLTW STUDENTS PARTICIPATING IN OTHER PRECOLLEGE ENGINEERING PROGRAMS AND OUTREACH EVENTS[1]

	O-SM	Sci. Olyp	Rob. Club	MSPE Disc. Eng.	M-S	Sci. Club	Disc. Ctr. STEM	TSA
High Schools								
Central	2	19	10	4	3	19	3	9
Glendale	0	1	7	3	0	2	1	5
Hillcrest	0	0	4	0	0	0	0	19
Kickapoo	0	5	0	0	0	1	0	0
Parkview	3	3	1	3	1	3	2	3
Middle Schools								
Carver	3	3	11	5	30	2	4	10
Cherokee	3	11	3	7	21	5	7	11
Jarrett	3	10	11	6	24	4	5	13
Pipkin	5	3	4	0	10	2	1	5
Pleasant View	0	2	12	10	26	1	5	0
Reed	4	2	5	5	9	1	6	2
ALL	23	56	70	53	151	40	39	77

[1]**O-SM**: O-Steam; **Sci. Olyp**: Science Olympiad; **Rob. Club**: Robotics Club; **MSPE Disc. Eng.**: MSPE Discover Engineering Day; **M-S**: Make Space; **Sci. Club**: Science Club; **Disc. Ctr. STEM**: Discovery Center STEM Week; **TSA**: Technology Student Association.

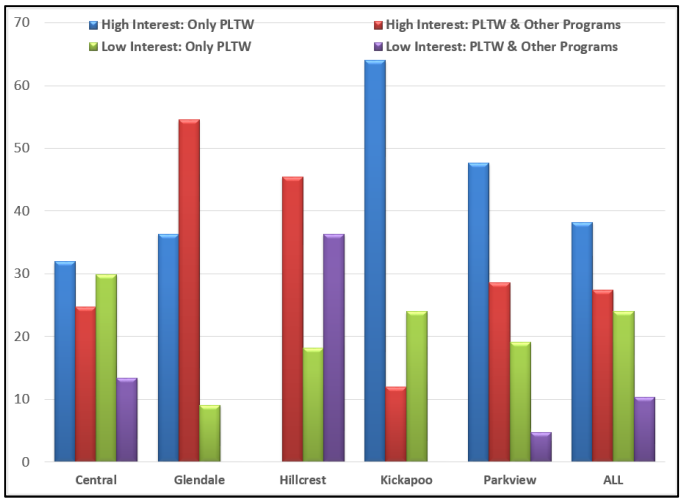

Fig. 1. Participation in PLTW and other programs vs. level of interest of students in Eng./CS/Studying Eng. in college for the high schools.

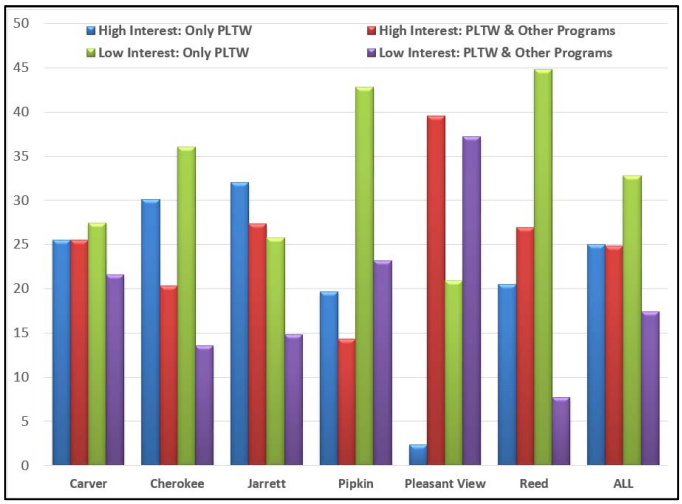

Fig. 2. Participation in PLTW and Other Programs vs. Level of Interest of Students in Eng./CS/Studying Eng. in College for the High Schools.

Table 4 provides the top three PLTW activities that students enjoyed in the program. It also provides the percentage of students per school who believed the skills from PLTW had influenced them to consider engineering as a posisble major for college. This can help more schools decide what projects or activities are most effective.

Tables 5 and 6 compares the in-school pre-engineering programs with external outreach programs. According to Table 6, the influence of PLTW in the middle schools may seem less but that is probably due to the fact that at some of the schools, the students (6th graders) had barely commenced the curriculum and thus had not been exposed to the Eng./CS components. There is a more significant correlation between participation of students in the in-school programs and their level of interest in eng./comp. sci. We can infer that teachers/readily available in-school programs have a greater influence in shaping the desires of the students. More partnership with intructors in the SPS is needed to enhance the effectivenss of the outreach programs in general. We need to expose students to programs easily within their reach. This survey was administered to only the PLTW middle and high school students. It will be worthwhile to analyze how many students are interested in engineering but not currently in the PLTW classes as well as their level of participation in other pre-engineering activities.

The demographic analysis of the MSU/S&T engineering students surveyed is presented in Table 7. It is important to note that the less than 1% of these students have been part of a PLTW program. The recent efforts to introduce pre-engineering education into the SPS curriculum via the PLTW is a welcome development. However, most of the students currently enrolled in the engineering program did not have the benefit of such program. When evaluating the pre-college programs that these students were involved in, Science Olympiad appears to have exerted a strong influence on decision to choose engineering as a college major (Table 8). In a follow-up brief survey administered via survey monkey, we also gathered that about 58% of the engineering students made a decision to study engineering before college. Thus, by exposing K12 students to engineering, we can take advantage of a significant opportunity to influence students' decision before enrolling in college. Love of math, science, electronics, interest in how things work and problem solving were top reasons given by college students as to what sparked their interest in engineering (Table 9). It is interesting to note that parents and family members were those reported by our population sample as having the strongest influence on their choice of engineering (Figure 5). Some engineering students also had prior work experience before enrolling in college which also influenced their decision to consider engineering as a major (Table 9). We can capitalize on this finding by designing outreach programs that support and inform family roles in encouraging the choice of engineering.

A limitation of this study is that even though the middle school and high school students surveyed exhibited some diversity, the MSU/S&T engineering students are predominantly white (Table 7) and about 30% of them are non-traditional students.

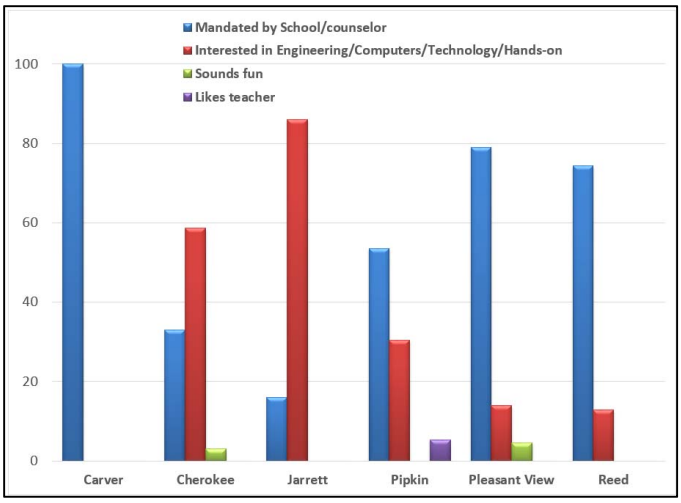

Fig. 3. Reasons given by Middle Sch. students for signing up for PLTW classes

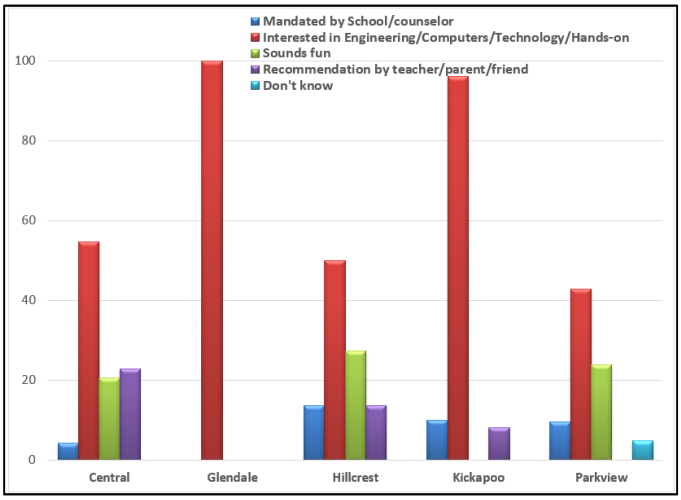

Fig. 4. Reasons given by High Sch. students for signing up for PLTW classes.

TABLE IV. TOP 3 ENJOYABLE PLTW ACTIVITIES BY SCHOOLS AND IMPACT OF PLTW SKILLS ON CONSIDERATION OF ENGR AS A COLLEGE MAJOR

School (# of students surveyed)	**Activities**	**Count**	**Skills from PLTW influenced me to consider Eng. for college**	
High Schools			***% Yes***	***%No***
Central (97)	Labs	42	49.5	50.5
	Building/ Design	34		
	Programming	9		
Glendale (22)	Building/ 3D Design	14	86.4	13.6
	Hands on Learning	3		
	Programming	3		
Hillcrest (22)	Design	13	50.0	45.5
	Robots	3		
	Hands on	2		
Kickapoo (50)	Building/ 3D Design & Modeling	27	64.0	32.0
	Hands on Learning	10		
	Inventor	6		
Parkview (21)	Coding/Programming/App design	12	47.6	52.4
	Building/ Design	2		
	Everything	2		
Middle Schools				
Carver (102)	Foot/ankle orthosis	41	37.3	57.8
	Building puzzle cube	37		
	Everything	9		
Cherokee (133)	Computer Programing/Apps	38	25.6	68.4
	Building/3D printing	32		
	Robotics	19		
Jarrett (128)	Coding/creating apps	32	46.4	53.6
	Robotics	13		
	Building/3D drawing	12		
Pipkin (56)	Building/3D drawing	13	23.2	75.0
	Foot orthosis	6		
	Design Process	5		
Pleasant View (43)	Videos	11	32.6	62.8
	Computer Programing/Apps	7		
	Building	6		
Reed (78)	Foot orthosis	24	25.6	65.4
	Building	3		
	Everything	3		

TABLE V. IMPACT OF PARTICIPATION IN EXTERNAL PRE-COLLEGE ENGINEERING PROGRAMS/OUTREACH EVENTS ON LEVEL OF INTEREST OF STUDENTS IN ENG./COMP. SCI./STUDYING ENG. IN COLLEGE

	O-S		**Sci. Olyp.**		**MSPE Disc. Eng.**		**Disc. Ctr. STEM**	
Schools	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*
Central (97)	3	0	13	6	3	0	1	2
Glendale (22)	0	0	2	0	2	0	1	0
Hillcrest (22)	0	0	0	0	0	0	0	0
Kickapoo (50)	0	0	5	0	0	0	0	0
Parkview (21)	2	1	2	1	1	2	1	1
Carver (102)	1	2	2	1	4	1	2	2
Cherokee (133)	1	1	7	4	2	2	4	3
Jarrett	1	2	0	0	6	1	2	3
Pipkin	1	3	1	2	0	1	0	1
Pleasant View	0	0	1	1	6	4	3	2
Reed	2	2	2	0	3	2	4	2
ALL	**11**	**11**	**35**	**15**	**27**	**13**	**18**	**16**

TABLE VI. IMPACT OF ON-SCH. PREMISES PRE-COLLEGE ENG. PROGRAMS ON LEVEL OF INTEREST OF STUDENTS IN ENG./CS./STUDYING ENG. IN COLLEGE

	Rob. club		**Sci. club**		**TSA**		**Maker Space**	
Schools	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*
Central	9	1	10	5	9	0	2	0
Glendale	7	0	1	0	4	0	0	0
Hillcrest	3	1	0	0	10	8	0	0
Kickapoo	0	0	1	0	0	0	0	0
Parkview	0	1	2	1	2	1	0	1
Carver	8	1	1	1	9	1	15	16
Cherokee	3	0	3	2	6	5	14	7
Jarrett	9	3	2	4	7	3	18	5
Pipkin	3	1	0	2	4	1	4	7
Pleasant View	4	6	1	0	0	0	14	13
Reed	4	1	1	0	2	0	8	1
ALL	**50**	**15**	**22**	**15**	**53**	**19**	**75**	**50**

TABLE VII. DEMOGRAPHIC ANALYSIS OF ENGINEERING COLLEGE SAMPLE SURVEYED BY GENDER, MAJOR AND ETHNICITY

Total # of Students	% Male	% Female	% EE*	% CE*	Ethnicity	
					%White	%Others
81	82.7	17.3	39.7	47.4	92.6	7.4
1st Generation College			*Yes* 17.9%	*No* 82.1%		
Involved in PLTW prior to college			*Yes* 0.07%	*No* 99.93%		

*12.8% of responders did not specify their major

TABLE VIII. NUMBER OF COLLEGE STUDENTS WHO HAD PARTICIPATED IN PRE-COLLEGE PROGRAMS AND EFFECT OF CHOICE OF ENG. AS A MAJOR

	Participated in Program	Influenced Choice of Engr. Major
O-STEAM	1	0
Project Lead the Way	4	3
Science Olympiad	12	11
MSPE Discover Engr. Day	4	1
Discovery Center STEM Week	1	0
Science club	7	6
Robotics club	2	2
Technology club	2	2
Maker Space	0	0

TABLE IX. RESPONSE OF COLLEGE STUDENTS AS TO WHAT SPARKED INTEREST IN ENG. AS A MAJOR

Reason	Count
Love of math/science /physics/drafting/ CAD/ electronics	29
Interest in how things work/problem solving	20
Salary potential/job security	17
Family owned/worked in Engineering company	10
Prior work experience	6
Interest in infrastructure systems/solar panel	5
Service to community	5
Designing things	4
Intro to engineering course in High school/Community college	5
Robotics	3
Encouraged by parents/teachers	3
Job Shadowing	2

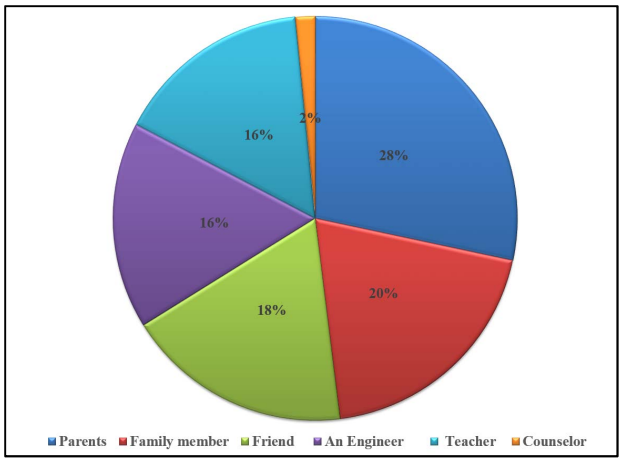

Fig. 5. Response to strongest influence on choosing engr. as a career.

CONCLUSION

In this work, we have analyzed middle and high schools students as well as engineering students in the Ozarks region to access the factors that are influencing their decision to pursue engineering as a career. The findings obtained suggest that we need to inform and engage the support of the families, especially parents, in the pre-college engineering outreach programs. Partnership with the local schools to strengthen the in-school premises programs may be a viable path to go to strengthen our engineering pipeline at the K12 level. An area of future work stemming from this research is the need to examine the effectiveness of engaging minorities in engineering in the Ozark region.

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APPENDIX

SPS ONE-PAGE SURVEY

School:

Sex: ____Male _____Female

Grade: 6 7 8 9 10 11 12 UG

Ethnicity: Caucasian African-American Hispanic-American Latino- American Asian Other (specify) _____

1. In what grade did you first get involved with **Project Lead the Way** (PLTW)?
2. Why did you sign up for PLTW class?
3. Which activities have you enjoyed the most in PLTW?
4. Have skills acquired in PLTW caused you to consider studying engineering as a major in college? __Yes ___No
5. On a scale of 0 – 5 with 1 being not all interested and 5 denoting very much interested, rank your level of interest in the following statements:

I am interested in engineering	0	1	2	3	4	5
I am interested in computer science	0	1	2	3	4	5
I am interested in biomedical sciences	0	1	2	3	4	5
I plan to attend college	0	1	2	3	4	5
I plan to study engineering in college	0	1	2	3	4	5

6. If you are planning on going to college, will you be the first in your family to do so? ___Yes ___No
7. I have participated in the following programs. (circle all that apply)

O-STEAM | MSPE Discover Engineering Day |Discovery Center STEM program |Science Olympiad | Maker Space |Robotics club | Science club | Technology club

8. Who has talked to you about engineering? (Circle all the apply)

Parents | Family member | Teacher | Counselor | Friend | an Engineer | Community Advocate

9. What three classes do you enjoy most at school?
10. What do you think would make an engineering career more attractive to you?

MSU ENGINEERING PROGRAM ONE-PAGE SURVEY

Engineering Major: Sex: ____Male _____Female

Ethnicity: Caucasian African-American Hispanic-American Latino- American Asian Other (specify) _____

1. What year did you start taking S&T engineering courses here at MSU?
2. What sparked your interest to consider engineering as a major before coming to college?
3. What hands-on projects/activities have you worked on or being involved with prior to college that motivated you to choose engineering?
4. I have participated in the following programs prior to college: (circle all that apply)

a. O-STEAM b. Project Lead the Way c. MSPE Discover Engineering Day **d.** Science club e. Discovery Center STEM program f**.** Science Olympiad g. Maker Space h. Robotics club i. Technology club

5. Which of the above programs were very useful in exposing you to engineering and influencing your choice? (list them by the referenced letter i.e. a, b…)
6. Who has been your strongest influence in choosing engineering as a career? (Circle all the apply)

Parents | Family member | Teacher | Counselor | Friend | an Engineer | Community Advocate

7. What three classes at high school do you think prepared you the most for engineering in college?
8. Have you been involved with **Project Lead the Way** (PLTW) prior to college? __Yes ___No

If yes, in what grade did you get first get involved?

If no, why not?

9. Are you the first in your family to attend college? ___Yes ___No