Application of DMAIC, Root Cause Analysis, and Community Interventions to Improve Engineering Awareness Among K-12 Students

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* Independent Research (guided by industry mentor)
** Scripps Ranch High School Students

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Abstract- Engineering remains one of the most impactful and economically valuable professions, however student interest in engineering careers remains disproportionately low compared to other fields such as medicine, business and science. This study applies industrial engineering and Six Sigma methodologies to identify and address factors contributing to low engineering awareness among K-12 students. A structured DMAIC (Define, Measure, Analyze, Improve, Control) framework was utilized to evaluate the problem, identify root causes, implement corrective actions and measure outcomes.

The study involved surveying 559 adults to evaluate career satisfaction by major, analyzing intended college majors of 526 college-bound students and collecting responses from 236 parents and professionals regarding barriers to engineering participation. Root cause analysis, Fishbone diagrams, Pareto Analysis and survey-based statistical evaluation were used to identify primary factors influencing low engineering participation. Results revealed that engineering careers demonstrated the highest life satisfaction scores, yet only approximately 12% of college-bound students surveyed intended to pursue engineering

To address the identified gap, a community outreach initiative was developed consisting of a children's engineering book titled "Maya and Jasper's Engineering Adventure" and poster sessions, school presentations, and interactive discussions were completed. Outreach activities reached 222 students through eight community events post-intervention measurements demonstrated approximately a 30% increase in engineering interest and 19% increase in clarity regarding engineering careers.
The findings demonstrate that industrial engineering methodologies can be successfully applied to educational and societal challenges. The study provides evidence that targeted outreach focused on increasing exposure and relatability can improve student awareness and interest in engineering careers.

Index Terms – Career Awareness, DMAIC, Engineering Education, Industrial Engineering, Root Cause Analysis, Six Sigma.

I. INTRODUCTION

Engineering plays a critical role in solving global challenges, yet many students have limited exposure to engineering careers. Students often recognize doctors, scientists, and business professionals but struggle to identify engineering disciplines. There is only a very limited interest in engineering majors and careers. This paper investigates the causes of this awareness gap and evaluates a community-based intervention designed to increase interest in engineering.
This paper, through surveys and interviews, identifies trends of majors of study, student participation gap within engineering as a major despite strong career promise. It continues to identify the leading causes of the gaps and attempts to address the cause by proactive corrective actions and measures its effectiveness
This paper evaluates life satisfaction among people in multiple professions and associated majors and identifies engineering as a major where people report solid happiness scores. Subsequent evaluation identifies a gap in interest in engineering amongst high school students and subsequently examines the reasons for this gap in engineering careers among K–12 students. The project finally attempts to raise interest in engineering and evaluates a community outreach initiative designed to address that issue. The project involved surveys, the creation of a children's engineering book, presentations at schools and libraries, and follow-up assessment of student

interest. The study explores whether early awareness raises curiosity among students and increases their interest in studying engineering.

The study also explores why engineering awareness is often lower than awareness of medicine, business, or science and discusses how targeted outreach can increase student interest.

The evaluation included interviewing 559 adults to evaluate their life satisfaction over 5 days and 3 unique places in the Scripps Ranch community. This data was used to assign satisfaction scores to each profession. Majors of 526 college-bound students over three years from the Scripps Ranch community were studied and it was noted that only 12% of students are interested in Engineering despite very high life satisfaction scores.

The community outreach study was conducted with over 222 students via 8 sessions between November 2025 and June 2026 to increase interest. The increase in interest was measured via unbiased questions at the end of each session. 4 questions were asked to all students and a measurable improvement in clarity of majors along with increase in interest in studying as a major was ascertained.

Through this process concepts of industrial engineering (Six Sigma – DMAIC method pioneered by Motorola in 1986, root cause analysis and basic statistical principles) were used during the study and through the project.

II. IDENTIFY, RESEARCH AND COLLECT IDEA

Problem Statement

Surveys conducted among peers and younger students revealed that many students could identify only one or two engineering fields despite the existence of numerous specialties. Misconceptions included the belief that engineering consists solely of building machines or writing code.

Methodology

The project used a mixed-methods approach. The following systematic evaluation methods were used to obtain information and draw conclusions. Each conclusion was followed by a new initiative of information collection and finally implementation of mitigation actions of publishing an engineering book via poster sessions and presentations.

1) A survey to ascertain life satisfaction scores was conducted from 559 adults. This survey was conducted over 5 days. The data collected was then analyzed and evaluated by major. Information regarding satisfaction score by major, percentage employed practicing the major was studied. Results can be seen in Table 1.
2) This was followed by evaluating the interest among students at Scripps Ranch High School. Data from admission decisions from three years (2024, 2025 and 2026) was studied. Data from 526 college bound students was analyzed and it was identified that over three years approximately 12% of students pursued Engineering as their college majors. Refer Graph 1 for the results of this analysis.
3) The findings from the analysis above prompted the team to verify the reasons cited as lack of interest. To verify whether the reasons for lack of interest were due to the causes identified during the interviews with Scripps Ranch students who were not interested in engineering, another survey was conducted such that parents of students and non-engineering professionals were interviewed to identify reasons for lower engineering participation. A total of 474 people were contacted, of which 236 people responded and answered as which are the top reasons for lack of interest in pursuing engineering as a major. Graph 2 demonstrates the results of the survey. Surveys were conducted before outreach activities to assess awareness levels. A children's book, Maya and Jasper's Engineering Adventure, was created to introduce engineering disciplines through stories and real-world examples. Presentations were delivered to schools and libraries. Follow-up surveys measured changes in student perceptions.
4) The team then decided to brainstorm a solution such that majority of the reasons could be addressed with that solution. A two-pronged solution was used such that one of the mitigation actions focus of introducing engineering to students at elementary schools by conducting live presentations in schools as well as holding poster sessions with students at bookstores, local libraries and other forums where children can learn more about engineering. The second focus area was to publish 100 copies and distribute them at libraries schools, raffle the books at the outreach events and other science centric events. Refer the implementation section of the paper

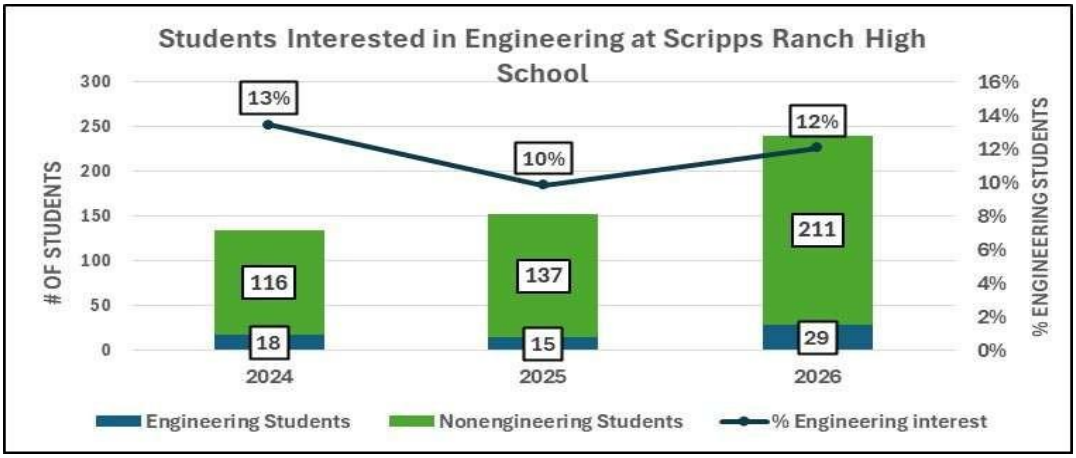
III. STUDIES AND FINDINGS

1) It was noted that despite very strong satisfaction outcomes only 5% of the population surveyed pursued engineering as a major (Refer Table 1)

Major	Happiness score	Total	% of all majors
Engineering	7.96	27	5%
Business Administration	7.90	111	20%
Economics	7.68	12	2%
Finance	7.60	12	2%
Accounting	7.52	17	3%
Computer Science	7.50	28	5%
Law	7.10	12	2%
MBA	7.99	34	6%
Commerce	7.43	22	4%
Medicine	8.30	5	1%
Political Science	7.00	12	2%
Education	8.20	55	10%
Psychology	7.25	29	5%
Other Majors	7.20	183	33%
		559	

Table 1 – Survey results and analysis of majors and their life satisfaction ratings

2) It was noted that approximately 12% of students out of 526 have committed to engineering as their major of study. Additionally, during verbal interviews of students who did not study engineering, information about their awareness and lack of interest in engineering was obtained. The most common reasons for lack of interest were cited as following –
   a. Engineering is difficult to relate to
   b. Inadequate engineering activity exposure
   c. Inadequate engineering related toys for boys and girls in formative years.
   d. Family members not exposed to engineering
   e. Inadequate exposure to engineering in school

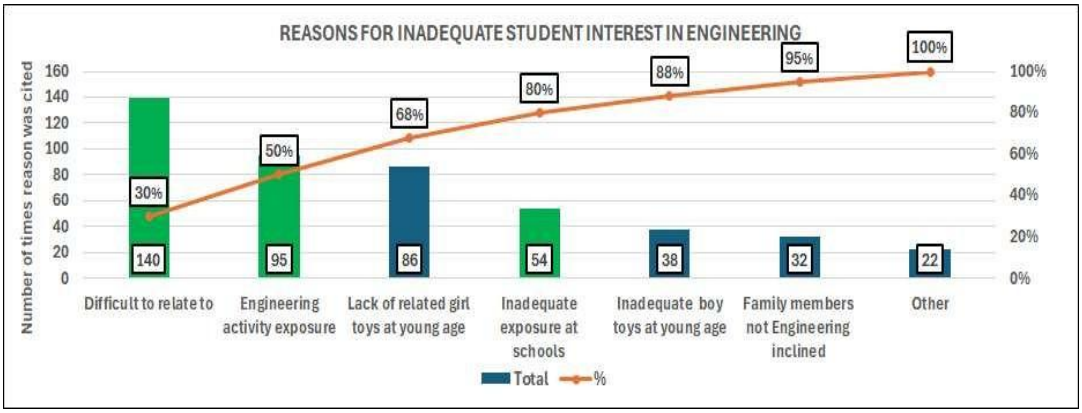


Graph 1 – Students by committed majors of study

Further research to examine the gap in enrollment (12%) v/s actual percentage of engineers (5%) indicated that approximately 50% of students who enroll for engineering either dropout or change their majors in college. This explained the gap in enrollment vs graduation rates for engineering.

3) Of the reasons that were cited by students from Scripps Ranch High School, three reasons overwhelmingly stood out as primary drivers behind the lack of interest –
   a. Engineering is difficult to relate to
   b. There has been very limited exposure to concepts of engineering
   c. Amongst girls, inadequate engineering related toys targeted towards young girls was a surprising reason cited for lower engineering participation by girls.

Graph 2 demonstrates the findings from the survey to understand causes of the gap identified within engineering majors. This indicates that approximately 62% of the problems are caused due to exposure or lack of relatability of the topic. (Highlighted in green)



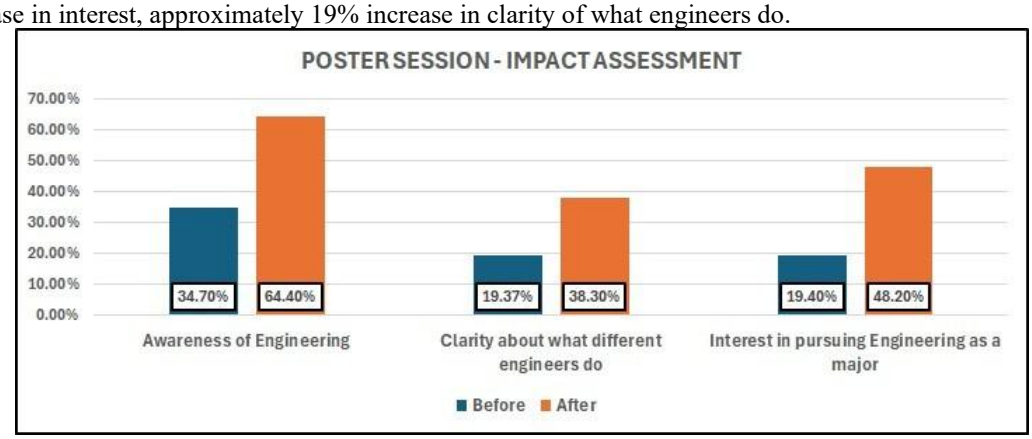
Graph 2 – Reasons for Gap in Engineering as a College Major to study

Implementation

The development process included researching more than 25 engineering disciplines and writing about each major. It was determined that the book to be written must be very relatable to children. The idea of using two young children (one boy and one girl) as the central characters of the book would help keep reading interesting. Images of the two characters were generated using Artificial Intelligence and their images were used to create a cartoon children's book. The first draft of this book had unclear pictures and was very long. After multiple iterations and cartoon definition that included a total of 9 drafts, a final version was decided for publishing. The process of iterative story telling took 45 days to complete. This was followed by getting publishing quotes from three different publishers along with their lead times. We then raised money for the book publishing via a fund raiser using the GoFundMe platform and self-funded the balance by doing a part time job. Editing help was obtained from two writers who had writing/publishing experience in the past. On the other hand presentations and posters introduced students to mechanical, civil, electrical, biomedical, environmental, aerospace, and industrial engineering. Interactive discussions encouraged students to connect engineering concepts to everyday life.

Results

Survey results demonstrated increased awareness and interest following participation. Students reported greater understanding of engineering fields and showed increased willingness to consider engineering-related careers. Measured results indicated approximately a 30 percent increase in interest, approximately 19% increase in clarity of what engineers do.



Graph 3 – Positive Impact of Poster/Presentation sessions on 222 students

IV. LESSONS AND DISCUSSIONS

Engineering Design Methodology

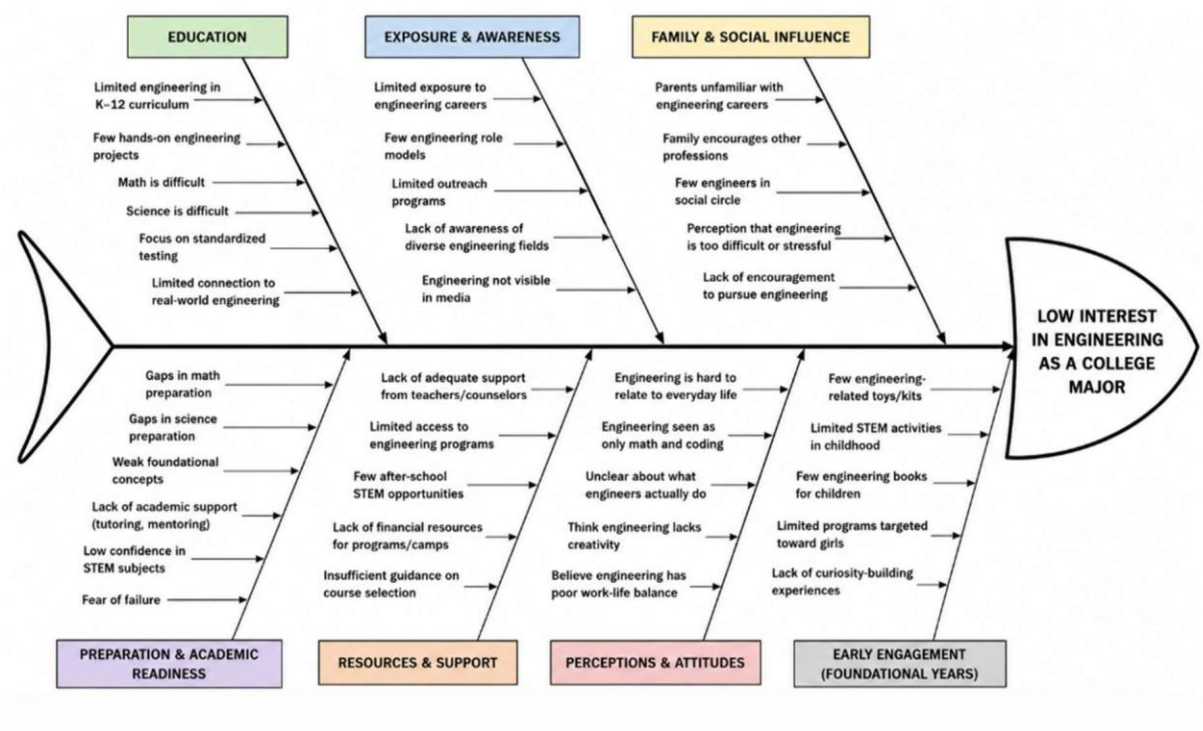
This project followed a structured engineering problem-solving approach consisting of five phases:

1. Problem Identification
2. Data Collection and Analysis
3. Root Cause Investigation
4. Corrective Action Design and Implementation
5. Verification and Continuous Improvement

Unlike traditional outreach projects, the objective was not merely to conduct educational activities but to systematically identify barriers to engineering participation and evaluate the effectiveness of corrective actions through measurable outcomes.

Root Cause Analysis

Initial observations suggested that engineering participation among students was lower than expected despite strong employment opportunities and career satisfaction outcomes. To identify the underlying causes, surveys and interviews were conducted with students, parents, and community members. Graph 4 illustrates the fish bone diagram of the causes



Graph 4 – Fish Bone diagram of the causes

The responses were grouped into categories and analyzed using a root-cause methodology. The results indicated that **most** responses could be traced to two primary causes:

1) Engineering concepts were difficult for students to relate to in their daily lives.
2) Students had limited exposure to engineering activities during their formative years.

Secondary causes included a lack of engineering role models within families, limited engineering-focused educational resources, and reduced availability of engineering-themed toys and activities targeted toward younger children.

These findings suggested that increasing exposure and improving relatability would likely provide the greatest impact.

Pareto Analysis

A Pareto analysis was conducted to identify which causes contributed most significantly to the participation gap.

The analysis revealed that approximately 70–80% of responses were associated with two factors:

- Limited engineering exposure
- Difficulty relating engineering concepts to everyday life

Based on the Pareto Principle, corrective actions were designed to specifically target these high impact causes rather than attempting to address all identified causes simultaneously.

This approach allows resources to be focused on the factors most likely to improve student awareness and interest.

Corrective Action Selection

Multiple potential solutions were evaluated, including after-school engineering clubs, engineering camps, mentoring programs, classroom activities, online resources, and educational books.

The selected solution consisted of:

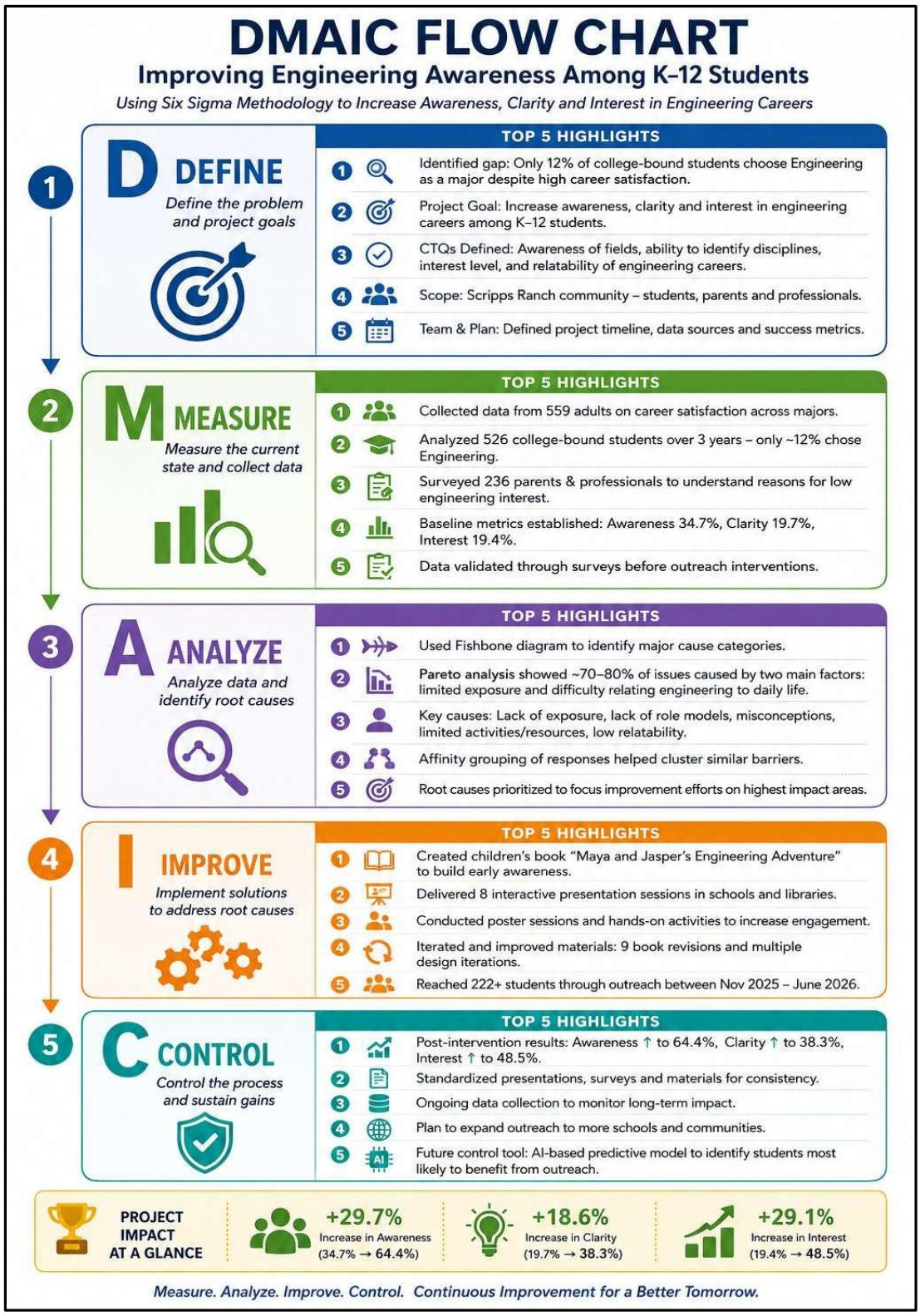
- Development of a children's engineering book
- Community presentations
- Poster sessions
- Interactive discussions

This solution was selected because it addressed both primary root causes while remaining financially feasible and scalable.

The book increased accessibility to engineering information while the presentations improved student engagement and provided opportunities for direct interaction.

Six Sigma Methodology

- Graph 5 below is the summary of the DMAIC methodology used as a guideline with major highlights throughout the project



Graph 5 – Sigma Sigma DMAIC Methodology

V. APPLICATION OF INDUSTRIAL ENGINEERING PRINCIPLES

Several industrial engineering principles were incorporated throughout the project.

- Data collection techniques were used to identify baseline conditions.
- Survey analysis was used to evaluate customer needs and perceptions.
- Root cause analysis methods were used to identify factors contributing to low participation.
- Corrective actions were developed based on measured data rather than assumptions.
- Finally, post-implementation measurements were used to verify whether the intervention produced the desired results.
- The project therefore mirrors the continuous improvement methodologies commonly used within industrial engineering environments. Principles of Six Sigma methodology (DMAIC) were applied during the project

Statistical Evaluation

- Individual Happiness scores were compared. Happiness scores for Engineering, Medicine and Business majors were compared to those with lower scores like Psychology, Political Science and Commerce. To determine whether the happiness scores among different professions (like Psychology and Commerce) are statistically different, a hypothesis test was conducted to compare their means, and the P value was examined. Two majors (Commerce and Psychology) were selected to be consistent with the sample size. All three majors had 29, 27 and 22 respondents each. Table 2 and Table 3 has the summary of Hypothesis test.

Use of hypothesis test to compare happiness scores (wrt Commerce)		
Ho = The mean happiness score for Engineering is the same as that for Commerce		
Ha = The mean happiness score for Engineering is greater than that for Commerce		
	Engineering	**Commerce**
Mean	7.96	7.43
Variance	0.615046154	0.344180952
Observations	27	22
Hypothesized Mean Difference	0	
df	47	
t Stat	2.703797447	
P(T<=t) one-tail	0.004756788	
t Critical one-tail	1.677926722	
P(T<=t) two-tail	0.009513576	
t Critical two-tail	2.011740514	
Conclusion - As the p value is low (0.004) we reject the null hypothesis (Alpha = 0.05). This means that the mean happiness score for engineering majors is greater than that for commerce.		

Table 2 – Hypothesis test of mean happiness score (Engineering vs Commerce)

Use of hypothesis test to compare happiness scores (wrt Psychology)		
Ho = The mean happiness score for Engineering is the same as that for Psychology		
Ha = The mean happiness score for Engineering is greater than that for Psychology		
	Engineering	**Psychology**
Mean	7.96	7.25
Variance	0.615046154	0.652142857
Observations	27	29
Hypothesized Mean Difference	0	
df	54	
t Stat	3.337080379	
P(T<=t) one-tail	0.000768851	
t Critical one-tail	1.673564906	
P(T<=t) two-tail	0.001537702	
t Critical two-tail	2.004879288	
Conclusion - As the p value is low (0.0007) we reject the null hypothesis (Alpha = 0.05). This means that the meaning happiness score for engineering majors is greater than that for psychology.		

Table 3 – Hypothesis test of mean happiness score (Engineering vs Psychology)

To determine whether the outreach activities produced measurable improvements, pre- and post-engagement survey responses were compared.

- The results indicated approximately a 30% increase in student interest in engineering-related careers following participation in outreach activities.
- Additionally, 20% more students demonstrated an improved ability to identify engineering disciplines and describe the role of engineers in society.

Although the sample size was limited to the Scripps Ranch community, the results suggest that targeted engineering outreach may have a positive influence on student awareness and career interest.

Human Factors Considerations

One observation from interviews was that many students viewed engineering as highly technical and difficult to understand. To improve engagement, the outreach materials were designed using age-appropriate language, relatable characters, and real-world examples.

The book featured both a male and female students to improve inclusivity and representation. These design choices were intended to reduce barriers to understanding while increasing student identification with engineering careers.

Cost-Benefit Evaluation

The outreach initiative required costs associated with publishing, printing, transportation, presentation materials, and event preparation. However, the program successfully reached more than 222 students through eight outreach sessions and distributed approximately 100 books. The total cost of the program was approximately $1700. Given that this increased the interest in

approximately 70 students. The cost for increase in a single student was approximately $ 24 which is relatively low for the outcome it will have on student outcomes.

The relatively low implementation cost combined with the measurable increase in student interest suggests that community-based engineering outreach may be a cost-effective approach for increasing awareness of engineering careers.

Future Expansion Strategy

Future phases of the project will include:

- Expansion to additional school districts
- Building an AI-based prediction model for quantifying the gains and using it for deployment
- Development of digital learning materials and posting it on www.youtube.com
- Translation into two languages (Spanish and Marathi)
- Partnerships with local engineering organizations like Scientella

These improvements would allow for larger sample sizes and more comprehensive evaluation of long-term impact.

VI. ENGINEERING IMPACT

This project demonstrates how engineering methodologies can be applied to social and educational challenges. Rather than assuming the causes of low engineering participation, the project collected data, identified root causes, implemented targeted corrective actions, and measured outcomes. The process reflects the fundamental engineering approach of identifying problems, developing evidence-based solutions, and continuously improving results through measurement and analysis

VII. LIMITATIONS

The survey and the associated outreach were focused solely within the Scripps Ranch community, which may not be a true representation of the entire population of US. All the answers were self-reported and not verified. Other causes for lower participation that were not in the survey were not investigated.
Several limitations should be acknowledged.

• The study was conducted within a single community (Scripps Ranch).
• Survey responses were self-reported and were unverified.
• Long-term retention of engineering interest was not measured.
• Additional contributing factors may exist beyond those captured in the surveys. These causes for lower participation that were not in the survey were not investigated.

VIII. CONCLUSION

This study demonstrates the successful application of Industrial Engineering and Six Sigma methodologies to address a community education challenge. Through systematic problem definition, measurement, root cause analysis, implementation of corrective actions, and post-intervention verification, the project achieved measurable improvements in engineering awareness and student interest.

The findings suggest that increasing engineering exposure and improving relatability at an early age can significantly increase student engagement with engineering and help strengthen the future engineering workforce. By reaching over 200 students and demonstrating a measurable increase in engineering awareness, the project provides evidence that targeted outreach initiatives can positively influence student perceptions of engineering careers.

The Maya and Jasper's Engineering Adventure project illustrates how a student-led initiative can create meaningful and measurable community impact. Future efforts could expand the program to additional schools and communities, allowing the approach to reach a broader audience and further contribute to the development of the next generation of engineers.

IX. APPENDIX

N/A

X. ACKNOWLEDGMENT

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