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Motivating Middle Schoolers to Be Engineers

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Gale Tenen Spak established Build Their Future, LLC in 2019 to provide talent and workforce STEM and soft skill development training and education consultancy appropriate for "cradle to gray" generations based on what she has learned over 26 years at NJIT. Between 1992 and 2018, Dr. Spak was Associate Vice President of Continuing and Distance Education at New Jersey Institute of Technology, Newark New Jersey. Through her oversight of NJIT's Division of Continuing Professional Education, she has had extensive experience in the areas of professional STEM workforce development and continuing education programming which are topics about which she writes and presents broadly. Her experiences include managing, developing, marketing, proposal writing, evaluating and implementing academic and non-credit programs for working professionals and job seekers who require new education and training to keep their skill sets at the cutting edge. The programs she designs involve collaborations among academe, industry, and government; and utilize, as appropriate, digital instruction and platforms. Recent awards include: "Made in NJ Honor Role" conferred by the NJ Manufacturing Extension Program on National Manufacturing Day, 2018; Leading Women Intrapreneur, conferred by NJ Leading Women Entrepreneurs, 2018; and Best 50 Women in Business, conferred by NJ Biz, 2016. In 2018, she was the Principal Investigator of three NJ Department of Labor and Workforce Development (LWD) grants: (1) Construction & Utilities Talent Development Center, (2) Construction & Utilities Talent Network, and (3) Technology Advisory Network (TAN). Among her numerous publications, her co-authored paper, M-0utreach for Engineering Continuing Education: A Model for University-Company Collaboration," was awarded one of five Best Paper awards out of 1700 submissions presented at the American Society for Engineering Education's 118th Annual Conference. Before joining NJIT in 1992, Dr. Spak was Dean of the School of Professional and Continuing Education at New York Institute of Technology, Old Westbury, New York, and, during America's first energy crisis, served as the Director of the Center for Energy Policy and Research and authored "how to" reports which were sent to every American Governor. She earned her Doctor of Philosophy in Political Psychology and Master of Arts from Yale University, and her Bachelor of Arts, magna cum laude, Phi Beta Kappa, in Political Science from Brooklyn College of City University of New York.

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Dr. Ronald H. Rockland received his B.S.E.E. and M.S.E.E. and Ph.D. in bioengineering and electrical engineering from New York University, and received an M.B.A. in marketing from the University of St. Thomas. After almost 25 years of industrial experience in research, engineering, marketing and sales management and general management with several high technology corporations, he joined New Jersey Institute of Technology (NJIT) in 1995 as an Assistant Professor. He is currently professor emeritus, Engineering Technology. Prior to retiring, he was the chair and professor of the Department of Engineering Technology, with a joint appointment in the Department of Biomedical Engineering. Previous to that he served as Associate Dean, Undergraduate Studies for the Newark College of Engineering of NJIT. His research in industry was in the area of pacemakers and defibrillation, and his research at Medtronic Inc led to five patents. He was a principal investigator for a three year, $1 million NSF grant entitled Medibotics:

The merging of medicine, robotics and IT, and was a co-principal investigator for a $2.5 million grant on pre-engineering workforce enhancement from the New Jersey Commission on Higher Education, as well as a principal investigator for a Whitaker Foundation grant. His current research was in biological signal processing, related to cardiovascular signals, and in enhancing STEM education through use of engineering principles. He has written over 50 articles in both journals and conference proceedings, in both the educational and biomedical fields. Dr. Rockland was the recipient in 2015 of the ASEE Middle Atlantic Distinguished Teaching Award, in 2004 of the F.J. Berger award, a national engineering technology award presented by ASEE, and a 2000 award winner in Excellence in Teaching for NJIT, was named a Master Teacher in 2004, and was the chair of the Master Teacher's Committee. He is also very active in the Engineering Technology community, have served in numerous capacities for the Engineering Technology Division (ETD) of the American Society of Engineering Educators (ASEE), most recently as the Chair for ETD, as well as serving as a commissioner on the Technology Accreditation Commission (TAC) for ABET. He was selected in 2011 as a Fellow of the American Society of Engineering Educators. He is currently a Professor Emeritus in the School of Applied Engineering and Technology of NJIT.

Linda Hirsch

Motivating Middle Schoolers to Be Engineers

Abstract

The paper will be a summary of the implementation and effectiveness of a one-week in-person workshop designed to introduce middle school students to engineering and what engineers do as part of an educational Summer Camp at Brookdale Community College, located in Lincroft, NJ. Other discussion highlights will include: research supporting the importance of introducing engineering to middle school students; the motivation behind the instructors' decision to conduct the program in a summer camp setting; the significance to the program's success of having had engineers and continuing education professionals design and teach the program; and plans for an expanded program during the summer of 2022, based on lessons learned.

Regarding the 2021 Summer Camp program, the engineering design process was the vehicle for demonstrating the work in which engineers engage and the NASA Mars landing in 2021 was the theme underlying each of the program's hands-on projects. Problem-solving was a key connector of the subject of science to engineering. Students were given the opportunity to solve problems just as engineers would while learning how engineers use science in their everyday work. The NASA Mars landing in 2021, due to the excitement it generated across the general population, was used as a theme to increase students' motivation to learn about and interest in engineering by engaging student teams in hands-on and fun real-life applications of the engineering underlying the Mars landing. This also provided a meaningful context for the middle school students to learn about science concepts, such as gravity, levers, and forces, as well as engineering concepts such as systems, solid structure construction, mechanisms, and machines. Students were also introduced to the profession of engineering, the many different fields of engineering, the multi-disciplinary aspects of engineering, and examples of different engineering work places. The introduction of the engineering design process to student teams included the design and construction of spinning tops, gyroscopes, Rattlebacks, and Rube Goldberg devices. Then, the teams of students were involved in engineering activities, using everyday materials, related to the Mars landing. These included the design and construction of a:

- parachute that can hold weight and descend slowly.
- space lander that can keep items (such as people) inside the lander after impact.
- paper Mars helicopter,
- model of a space habitat.
- working robot arm.
- Mars rover.

An end-of-program survey found that the program did increase students' interest in engineering and knowledge of engineering careers by providing them with challenging real-life applications of engineering.

Introduction

This paper describes a one-week morning summer program entitled, 'Becoming an Engineer." The program was provided for middle school students to introduce them to the engineering discipline and what engineers do and was the vehicle for demonstrating the work in which engineers engage. Through a program Students were also introduced to the profession of engineering, the many different fields of engineering, the multi-discipline aspects of engineering, and examples of different engineering work places. They were shown the different types of engineers that worked on the Mars landing project, which included: aeronautical engineers; chemical, material, and metallurgy engineers; communication engineers; computer engineers; electrical and electronics engineers; mechanical engineers; nuclear engineers; and systems engineers. Students were also shown a brief history of engineering and what the world might look at if we didn't have engineers. The program was designed to provide students with insights into the diverse engineering fields, and a perspective of how engineers function as problem solvers in the real world.

There continues to be a concern that our nation will not produce a sufficient number of scientists and engineers in the years ahead. The pipeline for producing future engineers depends upon the exposure of students to quality science and mathematics instruction as an overlapping and interdisciplinary enterprise, throughout the educational pipeline [1], [2]. It is generally accepted that completion of the math and science curricula in high school serves as the gateway to college, a major in an engineering field, and an engineering career. Programs for high school students have been helpful in developing the excitement of science, mathematics and technology in the students so that they would consider careers in engineering and science. However, interventions in student academic programs need to go back to the fifth grade or earlier, when they can be exposed to appropriate science and mathematics that include hands-on, problem-solving experiences [3], [4]. In addition, research by educational psychologists and the policies and procedures of the Summer Program operation suggest that a particularly apt age range for the program would be middle schoolers.

This program was designed as an academic enrichment and fun experience which provided the middle school students an exposure to the "engineering design process" (EDP) as a demonstration of how engineers think and do their work.

The problem solving process is considered a key connector between the subjects of science and engineering. Utilizing the engineering design process, students were given the opportunity to solve real-world problems just as engineers do while learning how engineers use science in their work. Science is so fundamental to what engineers do that essentially engineering is putting science to work [5]. Students were able to utilize physical science concepts to conceive, construct, test, and analyze the design of a product. They were also able to reconstruct, retest and reanalyze results to determine whether design modifications were effective, demonstrating that engineers not only create new products, but they also redesign them to make them work better.

Working in teams, the students were presented with the real-world challenges that actual engineers had to confront before there could be a successful Mars landing. How did NASA land a rocket on the moon? How much weight can a building hold before it collapses? According to some NASA engineers, the landing on Mars in February 2021 was one of the hardest technological feats human beings have ever attempted, since the rover was approaching Mars at 12,000 miles/hour, a velocity that had to reach zero when the rover was deposited on the surface of Mars [6]. This required a landing device that included a heat shield, a parachute, rocket thrusters, and a sky crane that finally could lower the rover and helicopter to the surface. The 2021 NASA Mars landing was used as a theme to increase students' interest in engineering by engaging student teams in real-life applications of engineering. This also provided a meaningful context for the middle school students to learn about science concepts, such as gravity, levers, and forces, as well as engineering concepts such as systems, solid structure construction, mechanisms, and machines.

Reasons Behind the Program's Middle School Focus

As previously mentioned, high school aged students are often the recipients of STEM programming and elementary school students may be too young to benefit as much from engineering hands-on experiences as would interventions designed for middle school children.

But other reasons which originate from the research of educational psychologists led to the selection of middle schoolers, in particular. Key among them is that it is never age alone which predicts the right time to effectively introduce STEM concepts. Indeed reception to and retention of knowledge in this domain can occur at any age with one element being the existence of supportive parents [7]. Given an opportunity to interact with parents, instructors can nurture their support. The opportunity to do this presented itself for middle schoolers. This was because the policies of the Summer Program dictated that parents of this age group (and younger) were required to personally both drop off and pick up their children at the beginning and end of each day's session. The same did not hold for high school students who were allowed to enter and exit the classroom on their own without further supervision, hence giving the instructors an opportunity to interact with parents and with intentionality to provide them with further supportive tips and information to be used at home. Also, unlike the limited role that parents play in determining when (and with what content) STEM classes are offered during the school year, it can be surmised that parents played a major role in helping their children wade through the many offerings in the Camp Catalog to end up selecting a program entitled, "Becoming an Engineer." Hence, this suggests the pre-existence of parents who would be supportive of their children exploring a career in this discipline in the future.

As an additional note, the timing of this program coincided with a rather remarkable scientific and engineering feat—the landing of the Mars rover just months before. Educational psychologists also have found that such occurrences present particularly favorable STEM "teachable moments" because the feat itself captures youngsters' attention [7]. Interest in "Becoming an Engineer" likely benefitted from the coincidence of an engineering milestone so fresh in mind.

Collaborative Program Development Process of Collegiate Engineer and Continuing Education Educators

Two of the co-authors originally conceived the idea of offering the summer program and were involved in it from start to finish. (Eventually, the other two co-authors played a significant role when, due to their particular engineering/science expertise, they were invited to lead particular sessions of the program.)

Regarding the sustaining 2-person team, one member is a PhD in engineering/science and a nationally recognized expert in K-12 STEM education; and the other, is a highly regarded collegiate Professional, Continuing and Online (PCO) leader. One might ask, "Why this unusual pairing?" And indeed the two team members discussed this issue in detail. It was acknowledged by both that simply exposing the campers to the selected materials through discussion and challenging hands-on projects would not necessarily result in effective learning outcomes and ultimately to increasing the pipeline of engineers. It was understood that at a deeper level, the process of learning at any age is complex even though it is often common in the engineering discipline for professors to focus primarily on content [8]. However, given years of experience, the team developing the curriculum did not subscribe to this line of thinking.

Rather, the differing perspective of PCO programs was acknowledged to be of equal importance. In a definitive essay tracing the import of attributes of activities within this domain at US universities, what is revealed is:

> …the presence of a persistent set of attributes or values that have given shape and direction to its programmatic activities and structure as well as defining the fundamental nature of continuing education. Prominent among these are social inclusiveness; a commitment to…responsiveness, innovation, agility, flexibility, and adaptability regarding the needs of learners…especially in constantly changing environments; pragmatism; and a commitment to assuring the academic value and rigor of its programs. [9].

That is, PCO professionals tend to have a heightened sensitivity to the needs of learners, which at times is referred to as being particularly “learner centric” and a seasoned proficiency with adapting rapidly to changing circumstances. Could there have been more of a need for such attributes in summer 2021 dwarfed by pandemic worries? Having a PCO professional as part of the team enabled the design and delivery of a curriculum and program which both accentuated the developers’ shared passion for increasing the pipeline of young people into the field of engineering and which honored their commitment to finding a way to overcome the barriers to effectively teaching science and engineering that were being imposed by the extraordinary circumstances happening during a pandemic. Covid-19 outbreaks were running rampant, resulting in almost all New Jersey students either studying remotely; or, if in physical classrooms, required to be masked and to sit 6 feet apart. Remote or in-class, neither type of learner had the option to learn STEM concepts by doing hands-on projects, for fear of further contagion through touching objects, let alone solving engineering challenges in teams, the latter being so central to the way this subject is learned and done.

On discovering that a Summer Camp would be running on a local community college campus and that all the programs were being planned for full in-person delivery, the collaborators seized this opportunity to design “Becoming an Engineer” as a program that could bring some fun back into the experience of learning STEM. During the preparation stage, there were several unknowns regarding the circumstances in which the program would be allowed to be conducted, all of which would be set by the college and/or the government. Would the students be required to wear masks and would they have to be seated 3 or 6 feet apart and precluded from doing hands-on activities? As it turned out, the college had made wearing masks optional but was still requiring all campers to be physically distant. Given the centrality of working in teams to effective engineering education, the collaborators were faced with a dilemma. The solution was to have a letter sent to the parents informing them that their children would be placed into the same 2-person teams through the duration of the program. This gave the parents an opportunity to withdraw their child if they objected, but none did.

The process of devising “Becoming an Engineer” in many ways resembled how any academic engineering course comes into being. That is, months before this program was to be scheduled and offered (and prior to even knowing that there would be enrollment in it), the two co-authors in the sustaining team began to collaborate on the development of the curriculum including choosing the Mars landing as its theme, and the age of the students to be taught (middle school); deciding on corresponding exercises/projects; selecting and preparing age-appropriate printed materials for class use and to be brought home to parents; identifying (by the engineer) and acquiring (by the PCO educator) of the everyday materials needed; and utilizing a course evaluation instrument at the program’s end (in addition to the Camp’s standard survey which was designed to assess only overall camper satisfaction). There was one component in the Program’s design process which differed from how colleges today recruit enrollees now that the import is understood regarding Diversity, Equity and Inclusiveness (DEI). The only roles the co-authors could play in this regard were limited to taking pains to emphasize inclusiveness in the Program description that was written for the Camp Catalog and to be attuned to this issue in the hands-on related materials distributed to campers (see Appendix) and in verbal interactions with the students who had picked this class for their camp experience.

The Program

The 4-day, one-week program consisted of 3-hour morning sessions, with the participants split up into 2-person groups. The curriculum designers purposely limited enrollment to 12 and the marketing efforts of the community college, during a time when Covid-19 concerns were ongoing, resulted in an enrollment of 10 students. Among them, 8 were male and 2 were female and all were either Caucasian or Asian determined by observation. The focus was on what engineers do and the engineering design process (EDP). The first day of the program started with an introduction to the field of engineering, what engineering do, the different fields of engineering, and the different work places for each engineering field, a brief history of engineering, and what the world would look like without engineering.

Each student was given a logbook into which, just like real life engineers, they could document their creativity and progress. They were provided with printed hand-outs and in some case templates to be used describing each day’s challenge projects. See Appendix. They also had a wide variety of materials from which to choose to use to construct projects purposely knowing that different teams were likely to select different materials to complete the same activity. Then student teams were introduced to the EDP process after which they explored its application to the design, construction, and redesign of an object relevant to the Mars landing. For each project, the team members sketched a design in their logbooks and designed a prototype, constructed it, tested it, redesigned it as necessary, and demonstrated it to the entire group. Student teams were encouraged to determine what was successful and what was not successful, ask questions, make recommendations, and, when appropriate, explain what could have been done differently.

The first design challenge for the student teams involved the application of the EDP to the design, construction, and redesign of spinning toys such as tops and Rattlebacks. Engineering a toy, such as a spinning top, allowed students to learn about the basics of engineering and scientific principles, and their applications, since they are usually based on principles of physics. A spinning top was also relevant to the program's theme, the MARS landing, since it is designed to be spun on its vertical axis, while balancing on the tip due to the "gyroscopic effect." All spinning objects have gyroscopic properties, such as rigidity in space and regular motion in which the axis of rotation describes a cone. Like a spinning top, a gyroscope is a spinning wheel or disc in which the axis of rotation (spin axis) is free to assume any orientation by itself. Applications of gyroscopes include the construction of gyrocompasses, which complement or replace magnetic compasses vehicles, including aircraft and spacecraft, to assist in stability, and maintenance of orientation over time, hence their relevance to the theme of the program.

The design challenge with the spinning top was for students to design a top that spins as long as possible within a designated area. Students were provided with everyday materials, including paper plates, CDs, DVDs, cardboard circles, washers, plastic bottle caps (with pre-punched holes in the middle), wooden skewers and sharpened pencils. Each student was also provided with a toy top as a starting point for designing their own devices.

Before moving on to the design of other products required for the Mars landing, the students were introduced to the subject of machines and to simple machines. They learned about different types of simple machines, with a focus on the lever, which was needed for several of the upcoming design challenges. The remainder of the program focused on specific devices relevant to the Mars landing, where the teams explored the application of the EDP and relevant science concepts using everyday materials. These included the design and construction of prototypes of:

- Model of Space Habitat: Although not needed for this Mars landing, there will be a need for such a structure when humans actually land on the planet.

  The engineering design challenge was to design and construct a model tower given only limited supplies and a time limit. The tower was to be as tall as could be made, but stable enough to stand up to a wind load that might be found on the planet. The limit on supplies paralleled real-world scenarios faced by engineers, who often are presented with design specifications which determine just how much material can be used. The towers were to be built for height and stability, as well as the strength to withstand adverse conditions that might be found on a planet, such as a lateral "wind" load. A successful tower would be one which would not topple over. Then, they were given additional time for redesign and construction.

- Lander that can keep items (such as people) inside after impact, and a parachute that can hold weight and descend slowly: How do you land something like the rover that is approaching the planet at 12,000 miles/hour, a velocity that had to reach zero when the rover is deposited on the surface of Mars? A unique challenge of the Mars landing was the development of the "entry descent and landing (EDL) system" [10]. Upon entry into the Mars atmosphere, the system had to decelerate from 13,000 miles per hour to zero in less than 7 minutes. This required a landing device that included a heat shield, rocket thrusters, and a sky crane that finally lowers the rover and helicopter to the surface. Thus, the campers were given two related challenges: design a lander and a parachute which would aid the landing of the spacecraft during descent, and which mimicked the remarkable parachute that actually was deployed during the landing.

The two specific challenges that students were asked to solve for designing the lander were slowing the descent of their lander and absorbing the energy of impact when the lander touches the ground.

First, they were asked to design a lander that included a cup with a ball inside it. And, they were not allowed to cover the top of the cup to keep the ball inside. They first tested their lander by dropping it from at least one foot off the ground. If the cup landed upright, didn't fall over, and the ball stayed in the cup, they were then required to drop it from a height of five feet in order to successfully complete the challenge. If the cup fell over, and/or the ball fell out of the cup, the students had to make design changes, and test their design again.

The second challenge was to design a parachute that could hold weight and descend slowly. The parachute could vary in shape and size. Also, consideration had to be given to air resistance and the amount of weight being used. The parachute had to be dropped from a height of five feet.

- Vehicle; i.e., Mars rover: The Mars rover was a carlike spacecraft that could be used to explore the surface of the planet.

  Students were challenged to build a rubber-band-powered-car that could race across the room (at least four feet). They were to build a prototype of the rover out of cardboard, and they had to determine how to use rubber bands to spin the wheel, and use the engineering design process to improve their rover based on testing whether it moved in a straight line and the distance that it moved. In redesigning the rover to improve its performance, students were asked to consider the following:
  - Did the wheels turn freely?
  - Did the rover travel in a straight line?
  - How far did it go?

- Robotic Arm: The rover had a 7-foot robotic arm incorporating shoulder, elbow, and wrist "joints" topped by a "hand" or claw with tools.

  Student teams were asked to design and build a working robotic arm from a set of everyday items. The robot arm had to be at least 18 inches in length and be able to pick up an empty Styrofoam cup. Teams of students had to agree on a design for the robot arm and identify what materials would be used. Each team was required to use the logbook to draw a sketch of their agreed-upon design prior to construction. The resulting robot arms were then tested and checked for range of motion and satisfaction of given criteria. Students were told that "error" can be part of a design process; that there is no "right" answer to an engineering problem, so that each team's creativity would likely generate an arm that was unique from the others' designed in the workshop.

- Paper Mars Helicopter: Since the actual Mars helicopter was expected to fly in an atmosphere just 1% the thickness of Earth's, it required large blades that could rotate five-to-ten times faster than a typical helicopter flying in Earth's atmosphere.

The challenge for the students was to build a paper helicopter given a copy of a template on plain paper. Then, just as NASA engineers had to try out different versions of the Mars helicopter before coming up with a final design, students had to experiment with the design of their helicopter to see what worked best; i.e., the design that fell the slowest from different heights. Students were asked to experiment with different designs, such as:

- Use a different type of paper or paper of a different weight.
- Construct a helicopter of a different size.
- Shorten or change the shape of the blades.
- Figure out a way to make your helicopter blades turn faster or slower.

Discussion

As students were seeking solutions to the engineering challenges, they were expected to keep a personal engineering logbook. In addition, for certain challenges, they were asked to respond to questions regarding their experiences as "engineers." The construction of a robotic arm provided some interesting responses to the following questions regarding their working as teams:

- How did working as a team help in the design process?

There was total agreement that it was helpful to work as a team. Among the comments were the following:

- "We can build on each other's ideas."
- "There are more ideas tossed around and we can help each other."
- "It helped by us all talking as a team and helping us talk about what we did wrong or need to change things."
- "It brought new ideas to the table."

- Were there any drawbacks to designing as a team?
  Most agreed, although there were a couple of "no" without explanation. Those that agreed had common issues such as:
  - "Conflicts can happen when you disagree."
  - "There can be arguments which waste valuable time."
  - "Figuring out what to do to make the claw."

- What did you learn from the designs developed by other teams?
  There were a couple of interesting comments.
  - More than one response said, "They used more cardboard than we did."
  - "They went for a design that looks like an arm."
  - "They were more complex than ours."
  - "We didn't pay attention to other people's designs."

An end of program survey found that the program did increase students' interest and knowledge of engineering and engineering careers by providing them with challenging real-life applications of engineering.
Participants were mostly agreed on the following:

- Camp was a good experience.
- Presentations were informative.
- Instructions for challenges were clear.

- Time spent for each challenge was adequate.
- Working as a team was fun.
- Camp was a fun experience.
- I enjoyed working as an engineer.

While there was general agreement on most categories, one category appeared to be an issue. Apparently, several of the 8th graders felt that the time provided for each challenge was not adequate. The planning for the next program for middle school students will take this and other lessons learning into consideration.

The Next Program

Following a process of continuous improvement, the co-authors are currently revising "Becoming an Engineer" to be offered to middle school students who will enroll in Brookdale Community College's 2022 Summer Camp.

Based on last year's student evaluations and the instructional team's observation of a small sample size of 10 campers, certain decisions have already been made to conform to the Camp's deadline in publishing a Catalog in a timely fashion through print and digital media outlets. With the four co-author's involvement remaining intact, these changes include lengthening the program from 4 to 5 days, extending the hours from three to four (plus a break for lunch) and increasing the enrollment cap from 12 to 16 students or a potential of 8 two-person teams. Another change is that a different engineer is pairing with the PCO educator to constitute the sustaining member of the team throughout five days.

Of signal importance in the 2022 curriculum development phase is the challenge posed currently by the absence of one of the two prime motivating factors used last year to increase the probability that campers would become more deeply engaged with the concepts and projects of the program. Absent in 2022 is an engineering feat of the magnitude of the awe-inspiring 2021 Mars landing, which the developers, with intention and pro-activity, had parlayed into "teachable moments" by associating all hands-on projects to it. Reinforcing what educational psychologists know so well about the power of teachable moments and speaking at the SXSWedu Summit in Austin, Texas on March 9, 2022, US Secretary of Education Miguel Cardona said, "We need to make sure that we're providing environments that meet [students] needs. 'Cause when those needs are being met, their ability—their bandwidth—for learning exponentially increases" [11]. The Mars landing last summer was such a motivational moment.

Hence a decision was made to strengthen and reinforce the second motivational factor which involves the role of parents. As mentioned above, Camp rules require that parents drop and pick up middle school aged children from the classroom, thus giving instructors an opportunity for interaction and discussion with them. However, in 2021, this opportunity played a lesser strategic role than the Mars landing. In 2022, it will be used as a motivator with more intention and through deliberate design. That is, while students will continue to be given age-appropriate printed materials about concepts to take home, in 2022, new supplemental materials and exercises will be developed for parents and provided to them in-person. Further, consideration is also being given to offering parents an opportunity to attend with their children the first few hours of the opening camp session for a similar purpose. Finally, after obtaining necessary permission, the camp instructors may snap pictures and take videos of and with the campers as they work on their projects as well as with campers, their parents and themselves to encode positive and ensuring memories of engineering.

Finally, the team will be turning the absence of an engineering feat in 2022 comparable to the Mars landing into an opportunity to broaden the scope of the hands-on projects to include but go beyond those exclusively related to the landing. Based on their own experiences, the team's engineers will be selecting different projects proven to have sparked youngster's imaginations about engineering. The tentative list of 2022 challenges and projects which cover a variety of engineering fields includes:

- Tower Design and Engineering Log Books – As part of the Tower Design challenge on the first day campers will be given detailed instruction on the purpose and use of an Engineering Log Book. Students will be given a logbook and taught proper techniques for using it during the remainder of the program.
- Mars Lander – The Mars lander challenge will still be used but enhanced to include the parachute challenge so that the challenge will be to design a lander that can hold weight and descend slowly to absorb impact and keep the cargo inside intact.
- Video Controller for Space Alien – The concepts of ergonomics and Human Factors engineering will be introduced through a space-themed scenario in which campers will be challenged to design a video controller for aliens who only have 3 fingers.
- Transport of Valuable Treasures – Based on Archimedes' Principle, campers will be challenged to design a water-tight vehicle that can transport a maximum weight-load.
- Exploration of Alternative Energy – The rubber band vehicle design challenge will introduce students to the concepts of alternative energy and aerodynamic design.

As the next Program offered in 2022 will be an expanded version of the 2021 program and potentially will include more students, a more objective evaluation is planned for both the students and parents. Illustrative of the kind of continuous process improvements for which engineers and PCO professionals are known, modified versions of evaluation instructions will be deployed which measure students' and parents' attitudes to engineering. These instruments, developed by some of the authors [12] have been successfully used extensively in prior research [13-15]. Also evaluations will be administered at the beginning and the end of the program to capture changes in students' attitudes towards engineering and interest in pursuing careers in engineering. Similarly, and because the role of parents will be accentuated in 2022, their pre- and post-program attitudes about engineering will be examined where feasible.

Conclusions

Being sufficiently convinced that their efforts in 2021 had inspired campers for future engineering careers, the team agreed to repeat the program, with changes, in Summer 2022. Major lessons learned include:

- Teaming of engineers and PCO educators gave the emphasis of the program a unique edge which is believed to have contributed to its success.
- The existence in 2021 of an exceptional engineering feat may have benefited the program's observed effectiveness in immeasurable ways.

- Administration of a team-designed end-of-program evaluation was more helpful to continuous process improvement than the Camp's instrument.
- Absent an ability to structure the program around a motivating major and recent engineering accomplishment comparable to the Mars landing, curriculum developers will need to be pro-active and intentional in nurturing ways to exponentially increase student's bandwidth to learn.

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Appendix

Resources for Hands-on Challenges

Spinning Top - https://frugalfun4boys.com/make-spinning-tops/

Windy City Paper Tower - https://www.asce.org/career-growth/pre-college-outreach/everyday-engineering
https://www.teachengineering.org/activities/view/duk_tower_tech_act

Safe Landing - https://discovere.org/stem-activities/safe-landing/
https://www.edutopia.org/article/whirligig-aerospace-challenge-lab

Parachute Design - https://www.jpl.nasa.gov/edu/teach/activity/parachute-design/

Make a Cardboard Rover -
https://www.jpl.nasa.gov/edu/teach/activity/roving-on-the-moon/
Educator's Guide - https://www.jpl.nasa.gov/edu/learn/project/make-a-cardboard-rover/

Make a Paper Mars Helicopter - https://www.jpl.nasa.gov/edu/learn/project/make-a-paper-mars-helicopter/
https://www.nasa.gov/sites/default/files/atoms/files/out-for-a-spin.pdf

Build Your Own Robot Arm - https://tryengineering.org/teacher/build-your-own-robot-arm/