Establishing a Balanced Organizational Structure for Large STEM Outreach Programs: Adopting the 10, 20, 30, 40 Rule

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Abstract - Developing, operating and maintaining a large STEM outreach organization can be a difficult task due to the variety of programs, number of outreach professionals involved and frequency of outreach events. This paper looks to document an established STEM outreach provider that has been in operation for more than 10 years and has provided pre-K through graduate school outreach, training and consulting. A review of the different STEM outreach programs will be presented. The organizational structure and method of operation will also be discussed, including impact on organization employees, organizational structure philosophies utilized, and the 10, 20, 30 40 rule that have enabled the organization to provide balanced outreach at all grade levels. Lessons learned will also be presented. The overall purpose of this paper is to document what a large STEM outreach organization may look like, so that other organizations can gain insight for their growth or sustainability.

Index Terms - Active Learning; Classroom; Education, Engineer; Invention; Innovation; Science; STEM; Outreach; Picatinny Arsenal; Volunteering; Workshops

I. Introduction
The importance of conducting Science, Technology, Engineering and Mathematics (STEM) outreach is well documented. The methods by which this is accomplished vary and depend on the specific needs of the student or STEM stakeholder being supported. Further the outreach provider can vary in size from single high school students doing experiments with younger students, to scientists and engineers (S&E’s) visiting classrooms, and to fortune 500 companies donating vast sums of money to build STEM infrastructure. Each of these has the potential to influence students and impact STEM careers. This paper looks to document what the authors consider a large STEM organization. The STEM outreach provider being described is one of the U. S. Army’s research centers, the Armament Research, Development and Engineering Center (ARDEC) located at Picatinny Arsenal, New Jersey.

The following sections will provide information on the organization, including how it grew into its current structure. Along with a review of the organization’s philosophies for optimizing its STEM outreach. The individual outreach programs currently provided by the Picatinny STEM Education Office are also described along with lessons learned.

II. Background
The Picatinny STEM Education Office is located in northwestern New Jersey and was created by the US Army Armament Research, Development and Engineering Center (ARDEC). Its location, mission, size and the composition of its workforce enable it to engage large numbers of schools at all levels of education and offer meaningful assistance with numerous emerging
technologies. It has the resources and experience necessary for a large scale education outreach program. Using this model is not meant to discourage smaller organizations from providing outreach, but instead to demonstrate several opportunities applicable to STEM supporters, whether they are independent STEM professionals or international corporations.

The location of Picatinny Arsenal in northwestern New Jersey allows easy access to large numbers of students. Approximately one million pre-K through 12th grade students from urban, suburban, and rural communities are within a forty mile radius. Ten universities are also within Picatinny’s area. The ARDEC mission at Picatinny Arsenal is to develop advanced armaments for the U. S. military. The wide range of STEM professionals needed to support such a diverse mission requires the talents of individuals from nearly all segments of the STEM community. Approximately ~2,500 scientists and engineers form the current workforce. With not enough students graduating with STEM careers there is concern over how the STEM talent for the future workforce will be met. Senior ARDEC leaders understand how a shortage of future STEM professionals will represent a threat to national security. More than ten years ago these leaders created a STEM Education Outreach Office knowing that today’s students will be tomorrow’s workforce and must be taught accordingly.

In most businesses the return on investment (ROI) is an important measure of success. This may be easily observed on an annual or quarterly balance sheet, but when the investment is in a future workforce it will require more time and nontraditional evaluative criteria. Educational outreach programs are marathons and not sprints. Indications of success may be elusive to the untrained eye.

ARDEC leaders knew the initial task was to select a person to manage the program. The talents of the Picatinny workforce were many. There were several award winning research scientists and engineers. There were accomplished military officers. However in this case they were entering a new area. The target area was education. The targets included young children, many just beginning their educational careers. The decision was made to find a former high ranking military officer with experience in the public school system including science teaching and administration.

Once found the program manager was allowed to add two more individuals to the office. The first selection was a person with advanced computer skills and bilingual fluency in English and Spanish. The team was completed with the addition of a patent-holding engineer with entertaining communication skills effective with teenagers. This team provided in depth knowledge of: the customer (the schools), on-line digital communications, creating inroads into the growing Hispanic population, becoming an engineer, what is involved in engineering, and what to expect as a member of a research and development team.

The first question to be answered was to determine why students were not selecting STEM courses. A simple survey was created, distributed to high school students and yielded evidence that approximately 80% of the students had no knowledge about what an engineer does. These findings have been validated in the literature on a larger scale by Cunningham’s work in the same area. Even the children of engineer parents had little understanding of what their parent(s) did at work. Quite simply, without knowledge of what engineers do there was little interest in becoming one. Even counselors and teachers could not explain engineering to students.

An effort was begun to convince ARDEC engineers to visit classrooms. Some were reluctant, but were reassured when told they only had to answer one question when interacting with
students. “What is the question?” they would ask. The question is the same one teachers get asked repeatedly. “Why do I have to learn this?” It wouldn’t matter whether the class was math or science. Unless the teacher had research and development experience in a prior career, the engineer would be the only one in the room able to supply the answer and the only one who could describe a real life situation with which the students could identify.

III. Philosophies of Operation

Fundamental philosophies or rules of engagement were developed to guide the selection of activities for the outreach program. Each of these philosophies stands alone as a method of operation and engagement but when combined optimize the organizations impact on outreach. The following six sections will detail these philosophies.

   i. Modifiable Content

The first rule was not to try to force one size fits all cookie cutter approaches on teachers or administrators, as commercial publishers and scientific supply businesses regularly attempt. ARDEC has achieved great success in the business world developing solutions to individual customer needs. The same logic applies to educational institutions. Allow the customer / school to state its goal(s). Then determine if ARDEC has the resources to supply the assistance needed. If so, a mutually agreeable course of action would be created resulting in each school receiving a unique outreach program custom developed for it.

   ii. No Cost

The second rule of engagement was that all assistance would be provided without cost to the school. As a U. S. Government organization Picatinny Arsenal cannot give money or equipment to the schools. It can provide guest speakers, role models, and technical knowledge as when visiting engineer role models bring unclassified show and tell items from their labs. To protect employees while making educational outreach support visits they are given special education salary accounts to which they charge the time they spend in schools.

   iii. Teacher Focused

The third philosophy is to give teachers as much assistance as possible. To gain the most benefit from a school visit the engineer mentors spend time with teachers answering their questions about the future technologies which may be headed into the classroom. This often becomes a very beneficial informal professional development experience. An engineer in the classroom may inspire 20 or 25 students. An engineer who inspires a teacher will produce a return on investment many times greater when factoring-in the students the inspired teacher will influence during his/her remaining career. This third fundamental rule gave the STEM Education Office its slogan, “Win the Teachers, Win the War, Lose the Teachers, Lose the War.” Providing professional development training for teachers is the cornerstone of Picatinny outreach.

   iv. Meet The Students at Their Level

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The fourth philosophy is to speak to students in the digital language of their generation and assist educators who were part of the old analog generation make the transition to digital. Effective communication is needed for effective education.

v. Creativity & Innovative Thinking

The fifth fundamental is simple and basic. Encourage CREATIVITY and INNOVATIVE THINKING from students, teachers and the scientist and engineer mentors. If any member of the STEM Education Office starts to rely on old 20\textsuperscript{th} Century outdated methods and programs, click on delete and send them to the “TRASH” bin. A constant review of how outreach is conducted and how students are changing is needed to ensure the material being delivered sticks.

vi. The 10, 20, 30, 40 Rule

The Picatinny STEM Education Office has developed a rule, internally established as the ’10, 20, 30, 40 Rule’. This rule is designed to ensure the outreach programs meet the overall need of the students. Regardless of what presentations are made to students there is no substitute for directly engaging them in actual scientific discovery by exposing them to inventing and innovating. They must be allowed to make mistakes and learn from them. To guard against depriving students of chances to fail, and chances to be creative, the outreach professionals should avoid telling them too much. The 10, 20, 30, 40 rule is a recommended educational clock to encourage student creativity. The numbers represent percentages of available time allowed for the challenge at hand.

10\% of the available time can be used to tell students what they should do to solve the challenge and perhaps allow the formation of integrated product teams.

20\% of the available time allows for acquiring background information showing what others have already done. It may be found with on-line searches.

30\% of the time can be used for the newly formed integrated product team to decide what needs to be done.

40\% of the time allows participants to show instructors, and themselves, what they can do. Participants must learn to communicate their ideas to others, defend their solutions, and formally present their team’s results. Modeling and simulation, especially if 3D printers are available, should be included.

Teachers can serve as members of the integrated product team but should not dominate the conversation. This model can also be applied for STEM outreach targeted for teachers. Obviously this model does not work in every case and situation. For example, in a lecture type event with a 100 students, it will not be a good fit. For other programs such as workshops, robotics team support and teacher training, this method gives the S&E professional a starting point to develop programs that are more holistic and provide stronger outreach. With these fundamental philosophies in place and a better understanding of the target student population, the Picatinny STEM Education Office constructed and adopted many different outreach programs. The next section details many of these outreach programs.

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IV. Provided Outreach Programs

As described in the previous sections the Picatinny STEM Education Office has been focusing on developing and delivering STEM outreach for the last 10 years. This includes conducting outreach in a diverse range of populations as illustrated in Figure 1 based on a survey of 51 Science and Engineering (S&E) professionals currently conducting outreach.6

![Figure 1. Age Demographics for Outreach Support](image)

The vertical axis represents the number of S&E professionals conducting outreach at specific target demographics. It should be noted that many of the 51 S&E professionals conduct outreach for multiple groups. With this large distribution of outreach demographics a multitude of programs have been developed, utilized or adopted from existing programs. These programs service many different STEM stakeholders, such as the student, teachers, administrators, parents and other STEM organizations. The following sections will provide brief descriptions of many of the STEM outreach programs provided by the Picatinny STEM Education Office.

i. In-Classroom Visits, Workshops and Assemblies

As indicated in the background section, one of the first outreach programs established by the STEM office was to send S&E professionals into schools to allow students to ‘meet an engineer’ through in-classroom visits, assemblies and workshops. These efforts have been detailed in depth by the authors in previous literature.6, 7, 8 Overall this method of outreach delivery has been found to be effective in reaching pre-K through graduate students and allows for the S&E professional to modify or bracket content to match the student and teachers needs. This type of in person contact makes engineering real and puts a face on the term engineer for the students. Working with teachers further assists the teachers with one of the most difficult parts of their job, staying up to date with rapid advances in technology. Lastly this form of outreach has been found to be very cost effective.6
ii. Scholastic Programs
In an effort to support and encourage students interested in STEM careers, multiple programs have been supported to encourage and to sustain student interest in STEM. Support can take many forms including local science competitions such as the Army’s Junior Science and Humanities Symposiums where highly motivated high school students often undertake research at a graduate level. This creates an opportunity for S&E professionals to review their work and mentor them. For students with less demanding aspirations Picatinny has experienced significant success with its STEM Video Competitions. Students create short STEM related videos for distribution on social media sites. Winning students receive prizes like cameras or GoPro’s. Virtual Science Challenges & Internet Based Outreach, while lacking the impact of personal interactions, can demonstrate effectiveness when other options are not available, as when living in remote locations with no STEM professionals available for hundreds of kilometers.

iii. Tours
School Field Trips to meet scientists and engineers in their actual laboratories have caused a higher percentage of participating students to desire STEM careers than other individual types of outreach. Student comments, made at out brief sessions immediately following the laboratory visits, repeatedly confirm the impact of seeing real people, in real labs, working on real projects as life changing in nature. Unfortunately by their restrictions (group size and interference with ARDEC missions) visits are very limited in quantity. The number of students able to participate is small compared to classroom visits made to the school by the S & E’s.

iv. Lending Library
Picatinny Arsenal also encourages employees to work with their own family members (children, grandchildren, nieces and nephews). This is accomplished by the creation of a lending library of STEM education equipment. Items such as robot kits, snap circuits, books on experiments and other items can be borrowed and used at home.

v. Summer Programs
Having fully immersive programs for students, such as summer camps, is another critical way to build excitement for STEM careers. The evidence of this can be found in the current literature which identifies links to summer programs and later higher level enrolment. The summer based programs developed and implemented by the Picatinny STEM Education Office have been fully documented in previous literature. When family members of employees participate in STEM activities at the arsenal parents are given the option to monitor the experience by watching videos immediately posted to Facebook. Parents are then able to be involved even when questioning “What did you do in school today?” during dinner table conversation yields the standard response, “nothing.” Summer programs also open the opportunity to involve multi generations in an attempt reach students through their peers and family members. Some work on Family Engineering outreach has been documented in an effort to create a stronger link between parents and future STEM students. To further expand in this area the STEM office developed a workshop and lecture series that has been conducted in the states library network. The lecture series in particular reached a very diverse age range, allowing
the program to inspire children, their parents and grandparents about the importance of STEM. Reaching the older population has the potential to be a STEM outreach multiplier for students due to the amount of quality time parents, grandparents and family members have with their children.

vi. Consulting
Beyond the writing of this paper, which in itself represents an effort to consult with other STEM outreach providers, the writers believe all organizations and individuals discovering new and productive outreach activities have a duty to share information. The importance of STEM in the 21st Century and beyond cannot be overstated.

vii. Research
As illustrated by this paper, the Picatinny STEM Education Office in recent years has made an effort to document the programs and methods it has implemented, in hopes of providing lessons learned and best practices for other STEM stakeholders. Beyond just documenting practices, studies and research have been completed 6,8 and are currently being conducted on the value of additional outreach programs to ensure that the organization’s efforts are effective and targeted at the correct age ranges.

viii. Teacher Training
Repeated reference has been made to the importance of the teacher in STEM education. Rapidly changing technologies and communications systems make it difficult for classroom teachers to remain current. Time and financial restrictions do not allow them to repeatedly take advantage of sabbaticals or leaves of absence for retraining. Whenever possible, education outreach providers should make serious efforts to bring the training to the teachers. Examples of this include a hands on 3D printing workshops a conducted for teachers and more in-depth week long training utilizing Materials World Modules15,16 focused on inquiry and design based teaching.

ix. Robotics Programs
Support for student robotics teams provides opportunities for engineer mentors to bond with students. Robotics is gaining recognition as a varsity sport in many areas of the nation with rapidly increasing numbers of students participating. Picatinny STEM outreach includes funding and engineer mentors for teams. No team receives funds unless it has a Picatinny mentor working with it. Funding is important but knowledgeable mentors are the most valuable support a team can receive.

Although all the programs outlined are excellent choices it may not be feasible for every outreach provider to implement and conduct all of them. Based on the authors experience, having actual S&E professionals interacting with the students has the most impact and should be a major focus of any outreach program.

V: Lessons Learned
As detailed in the previous section ARDEC has had multiple opportunities to pilot and evaluate several programs and/or strategies for STEM educational outreach. Each of these methods of delivery have proven to be effective when used at the right time and place. To expand on this the following discussion outlines general suggestions when developing and implementing these types of programs and are meant as lessons learned for other outreach providers.

1. Select activities based upon what will be needed in the future, not necessarily what is being done now. Most students currently in school will not be joining the workforce for another ten years. The younger the students the more future oriented the activities should be. Much of what is being done today could be obsolete in ten years. The best programs are usually those which update themselves on a regular basis. Review and update outreach activities every year.

2. Avoid one size fits all cookie cutter approaches. Schools, like their students, are different and are best viewed as individuals.

3. Insure the teacher will have an important role in the program. Expect to supply additional teacher professional development support.

4. Select activities that show engineering with a total skills approach stressing teamwork and communication. Knowledge of how and where to get information is more important than memorization of facts.

5. Do not ignore additional opportunities to promote STEM. Consider involving libraries and civic organizations. Youth programs such as scouting and 4H can provide STEM motivation for children.

6. Remember the benefits participation in STEM educational outreach gives to your co-workers and employees. In a recent survey conducted at Picatinny Arsenal with STEM mentors, 98% reported increased job satisfaction, 96% wanted to continue providing outreach in the future, 71% reported increased personal work motivation and 33% believed their career was advanced by participating in STEM educational outreach.17

7. Do not forget to be creative and innovative with your own programs. As in engineering itself, fear of failure may be your greatest obstacle.

VI. Conclusions

Conducting outreach is a critical tool that should be utilized to inspire young minds to pursue STEM careers. The examples presented are only samples of possible STEM based workshops. As the current generation of STEM professionals disappears from the active workforce, let its greatest contribution to the world be passing the fire of creativity to the next generation using the torch of education.
Bibliography


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