AC 2010-783: NDEP-SUPPORTED K-12 STEM OUTREACH ACTIVITIES OF THE US AIR FORCE

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Abstract

The National Defense Education Program (NDEP) is building a foundation for the future STEM (Science, Technology, Engineering, and Mathematics) workforce needs of the Department of Defense (DoD) by supporting science and math programs at the pre-college, undergraduate/graduate, and faculty/postdoctoral levels. At the pre-college (K-12) level, NDEP-supported outreach activities feature in-school, summer camp, and after-school activities with particular emphasis on math-focused, DoD scientist-and-engineer mentored, hands-on, problem-based learning experiences. This paper is devoted to describing both the composition and the assessments of two K-12 level, NDEP-supported, outreach activities of the U.S. Air Force.

Background and Motivation

The DoD recognizes the downward trend shown by U.S. students in their knowledge of and their participation in STEM as an area of critical concern to national security. Basic science and mathematics competence, gained in grades K-12, form the foundation of an educated, capable, technical future work force for DoD. The objective of NDEP is to support the education and development of such a future workforce by establishing a DoD-wide program to invigorate the science and mathematics curriculum, to enhance teaching skills of science and mathematics teachers to deliver the curriculum, and to increase the level of awareness, interest and active participation of students in STEM activities, projects, and academics. The overall strategy is to have DoD scientists and engineers partner with educational institutions to make direct connections between the curricula and the practice of science and engineering.

The motivation for such educational outreach programs is well known. Among the features that such programs are designed to include are providing real-world exposure to the use of science and engineering for middle and high-school students, enhancing the technical literacy of the general population, and increasing the number of U.S. citizens earning degrees in science and engineering.

Two Air Force K-12 programs will be described. They are the Dayton Regional STEM Center Partnership at the Wright Patterson AFB (WPAFB), OH, and the Air Force Research Laboratory (AFRL) La Luz Academy at the Kirtland AFB (KAFB), NM.

The Dayton Regional STEM Center Partnership

WPAFB’s AFRL/XPPD, Domestic Partnering Branch, was selected by DoD as the coordinator responsible for the NDEP implementation in the state of Ohio. The selection was made based on the strong series of on-going STEM programs at AFRL been managed by XPPD. One of these programs is the Dayton Regional STEM Center partnership. The Center was created in 2007 via a National Governors Association competitive process to be the hub of STEM curriculum design, training and support for educators in order to advance the goal of preparing all students with the
skills and knowledge to participate in the high-demand STEM careers of the future. The Dayton Regional STEM Center is an unprecedented partnership that combines the strength of education professionals with the realities of industry needs, allowing students to make the connection between what they are learning and how it will be used in future careers.

**Lesson Plans** – The Center develops inquiry-based, hands-on STEM curriculum utilizing regional workplace sectors or clusters that map to real-world work being done at the AFRL in the areas of sensors, power/propulsion/energy, advance materials/manufacturing, air systems and medicine/human performance. The Center works closely with AFRL STEM Fellows to develop inquiry-based/hands-on instructional lessons based on AFRL work in order to capture the real-life connection between the study of math and science and the use of these topics in professional practice. AFRL STEM Fellows are AFRL employees at the WPAFB who volunteer two hours per week to participate in the development of a STEM curriculum in partnership with teachers, university professors, and industry. The Center, in conjunction with the AFRL NDEP coordinator, provides STEM Learning Modules or kits to complement the lessons as necessary. Once the curriculum is developed, piloted, and documented, the Center works with the AFRL STEM Fellows and the AFRL NDEP coordinator to identify AFRL scientists and engineers to deliver parts of the curriculum on site at schools in the region. As lessons are finalized, the Center migrates them across grade levels vertically, and horizontally. Final curriculum units fully piloted and approved for use are provided to the AFRL NDEP coordinator to be shared with other NDEP coordinators across the DoD.

The program has been delivered to approximately 6,000 children in 18 school districts in the greater Dayton area. The 14 lesson plans which have been developed to date range from battery design and the physics of reaction propulsion systems to aspects of color perception in aircraft cockpit design ([http://www.montgomery.k12.oh.us/content_page2.aspx?cid=72](http://www.montgomery.k12.oh.us/content_page2.aspx?cid=72)). Each lesson contains connections with the science and mathematics areas of the Ohio Academic Content Standards and separate sections devoted to Technology Connections, Interdisciplinary Connections, Critical Vocabulary, Timeframe, Materials and Equipment, Safety and Disposal, Pre-and Post-Questions and Discussion Rubrics, Instructions for Students and Teachers, and Career Connections.

**Professional Development** – The Center, in cooperation with AFRL and higher educational institutions in the region, develops professional development training experiences in STEM in order to build teacher and leadership capacity. Teachers, principals, and superintendents participating in the STEM Center training are exposed to intensive engineering experiences at the AFRL facilities. The engineering intensive experiences content is coordinated by the Center with AFRL personnel to match the content of the STEM curriculum developed for the students.

Professional training of teachers, principals, and superintendents at the Dayton Regional STEM Center is provided in five modules:

- STEM Center Curriculum
- Engineering is Elementary
- Inquiry Coaching
- Summer Training Institutes
• Engineering Intensive Experiences

**STEM Center Curriculum** – As part of the curriculum design process, teachers are involved in executing the curriculum for specific lessons. They are guided by either STEM Fellow teachers, WPAFB personnel, or both. This is performed in a role reversal type environment where the teachers become the students. Sessions are conducted by cluster or technology area. At the end of each lesson, AFRL scientists and engineers then bring real-world equipment and demonstrations to illustrate how the concepts covered in the lesson are actually used.

**Engineering is Elementary** – This section is conducted for K-3 teachers and is designed to introduce the Boston Science Museum’s Engineering is Elementary series. Teachers are trained in the proper delivery methods and get specific examples on how to relate the concepts to situations happening in our region.

**Inquiry Coaching** – Teachers go through an intensive series of activities designed by the Center to define, explain, and utilize STEM concepts. Some of the topics covered are: keeping control in an inquiry-based classroom, preparing inquiry-based lessons teamwork, critical thinking concepts, moving from lecturing to discovery, and “STEM Education–What Is It?”

**Summer Training Institutes** – This training provides discipline specific (math, science, and engineering) training with technology as the centerpiece. Real-world technology concepts are explored and used as the guiding principle to generate specific learning concepts. AFRL scientists and engineers explain real-world technology concepts, work with teachers in the laboratory, and then dissect these technologies into learning concepts. This training is complemented by tours to AFRL laboratories or to our “outside the fence” research institutes.

**Engineering Intensive Experiences** – This is a one-week, on-site experience for teachers in which they either observe or participate in research been conducted in AFRL, industry, or university laboratories. Teachers are assigned a mentor who will explain all aspects of the project and how it relates to STEM education. Teachers have told us that this is their favorite part because they had no idea of the kind of research that happens in our region, their horizons are expanded, and they are now able to expend the classroom experiences they provide to the students. Being able to explain to students how the concepts that they are learning about relate to the real world provides a benefit that inspires all.

**Assessment** – Teachers participated in intensive week long, 40-hour summer institutes in 2008 as part of their professional development. The main purposes of the summer institute were to enhance teacher content, pedagogical content and processes knowledge, enhance teacher attitudes and dispositions toward best teaching practices, enhance teacher self-efficacy through attitudes of preparation in content and teaching skills, and to introduce the research-based curriculum.

**Changes in Teacher Content Knowledge**—Teacher content knowledge changes were measured with pre/post content tests prior to and after the summer institute component of the professional development. The tests were a mixture of multiple choice, extended answers, and in some cases performance assessments.
Table 1 indicates that, overall, the 196 teachers who participated in the summer institutes significantly increased their content knowledge. It is also interesting to note the relatively low pretest scores of the teachers, indicating their initial low content knowledge.

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<tr>
<th>MATH</th>
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<th>Post-Test Mean %</th>
<th>Normalized Gain</th>
<th>p-Value</th>
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Table 1. Results of All Participant Teacher Content Knowledge Changes Summer 2008 Academies (N = 196)

Changes in Teacher Attitudes, Dispositions, Perceptions of Preparedness, and Practices—
The perceived self adequacy of science teachers significantly increased with regard to how well prepared they were to implement best teaching practices such as providing concrete experience before abstract concepts, developing student conceptual understanding of science, taking students’ prior understanding into account when planning curriculum and instruction, making connections between science and other disciplines, and using informal questioning to assess student understanding. Additionally, math and science teachers felt better prepared in the science and math content of their summer institute after completion of the summer institute.

The teacher practices were evaluated using the RTOP (Reformed Teacher Observation Protocol), which is a tool that was developed by researchers at Arizona State University to evaluate inquiry-based instruction. Originally, 17 math teachers participated in the professional development program. Of these, only 5 completed math professional development and taught math lessons for which pre and post RTOPs were done. Since N is so small, only descriptive
statistics were used for this group. Overall, the 5 teachers had a pre-RTOP score of 32.2 (SD 19.22) and a post RTOP score of 56.8 (SD 29.01) with each of the construct means individually increasing. 29 science teachers completed pre and post RTOPs and taught science lessons for with pre and post RTOPs were completed. Significant increases in pre and post RTOPs were found, and significant increases in each individual construct of the RTOP were also found.

In summary, both math and science teachers increased their RTOP scores after completing the professional development and utilizing the new curriculum. This indicates that teachers were teaching with more inquiry, developed better classroom culture, and demonstrated better pedagogical content knowledge in their classrooms.

The AFRL La Luz Academy

The AFRL La Luz Academy (http://www.vs.afrl.af.mil/LaLuz/) was established at the KAFB to encourage students to pursue STEM studies. It is an outgrowth of the Students Planning and Conducting Engineering (SPACE) program begun at the Kirtland AFB in 1992 as a part of its Technology Transfer for Education (TTE) Program.

The TTE strategy is to create a hands-on, technology-enriched program which keeps students engaged in STEM-related activities starting in the fifth grade and progressing through middle school and high school by providing a bridge for transitioning into successive modules, called Flights, as they move up from one grade level to another, and by providing leadership opportunities for students to mentor younger students based on their previous experience. The development plan is based on systems engineering principles where both in-house development of STEM curriculum modules and the integration of outside curriculum are added as resources and technology transfer opportunities become available.

The Flights – Ideally, students would progress through all of the Flights; however, since school participation is based on school and teacher selection, that progression is often not possible for the students. For this reason, each Flight has been designed to stand on its own and not require a previous Flight as a pre-requisite. In the following sections, we will discuss each of these Flights and the summer teacher institute.

The Mars Missions Flight (5th Graders) – Each year, over 2000 students from throughout the state of New Mexico are involved and carrying out a simulated mission to Mars. This Flight is based on the Challenger Center’s Marsville program and has been modified to include Air Force technologies and terminologies. The program begins with a day-long training session for teachers who then go back to their classrooms where they divide their class into student teams. Each team is responsible for completing a series of base operations including designing a mission patch, designing and building a life-support system model, and measuring and cutting pieces of plastic which will be used to build life-size habitat structures and linkage tunnel. Each team is responsible for 1/3 of the plastic pieces which comprise the structure. The remaining
habitat pieces are provided from student teams from other schools/cities. In addition, each student team is asked to create a musical saga which describes their imaginary journey from earth to mars. On link-up day, all of the teams come together to carry out their mission. The student teams must go through a series of check stations to assure they are ready for the mission. These check stations include:

- An inspection of their plastic pieces.
- Briefing stations where student teams provide a technical briefing describing how their life support system will function in the harsh mars environment and a description of their mission patch.
- Lunch weigh stations where student team’s lunches are weighed and inspected to assure the lunches are within allowable weight, packaging, and nutritional parameters.
- A performance station where each team performs their Saga.

Manning these check stations include both scientists and engineers from the AFRL and other technology-based organizations and students participating in one of the middle-school Flights. These students are part of Mission Control and are also there to trouble shoot and assist the 5th grade teams throughout the day.

After the student team has progressed through the check stations, the team then finds the location of their assigned habitat and links-up with the two other teams from two other schools. When directed by the Colony Commander, they begin assembling their habitats. The habitats are made out of the plastic pieces and inflated with box fans.

*The DoD STARBASE Flight (6th Graders)* – In 2003, AFRL La Luz Academy was selected as the first regular AF unit in the DoD STARBASE Program (http://starbasedod.org/). Teachers bring out their classes for five non-consecutive days during the school year of STARBASE authorized curriculum. This curriculum includes:

- Newton’s Laws of Motion
- Forces of Flight
The model rocketry curriculum (fourth item in the above list) has been developed in partnership with the Albuquerque Rocket Society and scientists and engineers from the AFRL and the AF Space and Missile Command. Students work in teams to build rockets that are 6-feet high and rise to an altitude of 2000 feet. During the build process, students are introduced to modeling and simulation software. Data from construction is used to feed a rocket simulation program in which students enter various launch conditions to simulate the projected rocket flight. On launch day, 15-25 rockets are launched and recovered. During this activity, every student is assigned a real-world launch responsibility. These roles include: Launch Control Officer, Range Safety Officer, Final Assembly Team, Spotters, Recovery Team, Data Manager and Meteorologist. The rockets are equipped with altimeters and the student recovery team uses GPS units to identify the location where the rockets came down. The data manager is responsible for recording actual launch conditions including angle of the launch rail to real time weather conditions. The students then return to the classroom where they are asked to compare the actual data to the projection of the simulation software. As part of the flight simulation program students learn to fly a plane. Volunteer pilots share their experiences with students during the process. Approximately 800 6th graders representing 30 classrooms participate in the DoD STARBASE Program.

*Fig. 4. Students and Volunteer Space Scientist Performing Final Assembly.*

*Fig. 5. Graphing Recent Sunspot Activity and Using Silver Solder to Build an LED Badge*
the AFRL. The two directorates are located on Kirtland AFB and are known as the PRS. Curriculum includes:

- Electromagnetic spectrum
- Properties of light
- Exploration with lasers and optics
- Satellite subsystems
- Learning electronic circuitry and soldering techniques to build their own light emitting diode badge
- Gyroscopes, and
- Space Environment including space weather

The Introduction to Systems Engineering Flight (8th Graders) – Eighth-grade classes come on base for three, non-consecutive days to learn the principles of systems engineering. Students learn about systems, the history of computers, binary math, flowcharts, BASIC programming, microcontrollers, and robotics. By the third day, students will build a Parallax, Inc. Boe-Bot® to maneuver three obstacle courses as part of a robotics competition event.

Fig. 6. Students Programming Their Robots For the Final Obstacle Course at the 2009 ISE Robotics Competition

The SPACE Flight (high-school students) – SPACE Flight is designed to give students the experience of real-world R&D. Students work in teams to develop their topic, plan the approach, conduct research and compile their results under the guidance of teacher sponsor and volunteer scientists and engineers (S&Es) from AFRL and other technology based organizations such as Sandia National Laboratory, and defense contractors. Students are encouraged to leverage this program by participating in other outreach programs such as the Team America Rocketry Challenge and New Mexico Robo Rave. One year, students from Eldorado High School
designed satellite doors using electromagnetic principles. The AF acquired the patent on their invention and students retained their rights as inventors.

The Summer Teacher Institute – In 2007, NM Tech received NDEP funding and a grant from the State of New Mexico to conduct a STEM Summer Teacher Institute as part of the AFRL La Luz Academy construct. Actually, the term, “Summer”, is misleading since both the teachers and their schools are required to make a year-long commitment to the program. Participating teachers receive a monthly newsletter to keep them informed about current and upcoming AFRL La Luz Academy events. The Professional Development Specialist follows up with the schools and teachers during the school year to see what progress is being made, to identify technology-based modules or mentoring support that would enhance the school’s success in STEM education, to assist in developing STEM lessons using a hands-on/minds-on approach, and to guide teachers in the use of data to improve math/science education. This can include assistance in using e-based instructional technology in the classroom. Teachers and principals are encouraged to attend a culminating Teacher Symposium in June to share their STEM lessons and experiences.

Assessment – Since its inception, it was recognized that assessment of effectiveness needed to be embedded in the program. This is particularly important given its longitudinal nature and a development strategy based on controlled evolution and continuous development. It is important in assessing any complex program that the parameters for evaluation are based on the objectives of the program. For AFRL La Luz Academy, the two main and inter-related objectives are:

1. Encouraging students at all levels to pursue studies in STEM areas by providing them with hands-on experiences in the use of and the development of technologies with an emphasis on encouraging those students who are traditionally under-represented in STEM careers.
2. Creating a pipe line to increase the number of students that are supporting DoD career fields through hands-on experience at all levels of their educational experiences.

Our goal is to motivate both the student and the teachers to follow up on the lessons learned at the Academy both through additional classroom curriculum and by the students pursuing such studies on their own. Since the purpose of the AFRL La Luz Academy is to motivate students to pursue STEM careers by giving them the experience of real R&D and by providing them with an understanding that inorder to pursue such careers, they need to have a solid background in the STEM disciplines.

Among the assessment tools which the La Luz Academy uses are:
1. Demographic Studies – To verify that we are reaching the population that we are targeting.
2. Pre and Post Tests – To determine the short-term (within the school year) impact on the students’ understanding of the STEM topics, and
3. Longitudinal assessment - To see if students are pursuing DoD STEM careers after graduation.

**Demographics** – The following figure reflects the demographics of students participating in all AFRL La Luz Academy Flights for 2008-2009. One can see from these results that the program has been quite successful in attracting both minority and female students. The majority of the students in the program are non-Caucasian, and they are evenly divided in terms of economic disadvantage and gender.

**Pre and Post Test Results** – For each middle school Flight, a pre and post test is administered to every student in order to assess the students’ knowledge content gains in the materials that are presented.

The pre/post test for the DoD STARBASE Flight is administered to every student participating in the program. Figure 9 shows the overall gain in the acquired knowledge of all students on a student-by-student basis.
Not only is there a significant improvement between pre- and post-tests, but the greatest gains have been with those students who scored the lowest on the pre-tests as can be seen by comparing the height of the magenta bars on the left hand side of the plot, representing the lower-scoring students, with the height of the magenta bars on the right-hand side of the plot, representing the higher-scoring students. This is good evidence that we are making a difference for those students who need it the most. Figure 10 shows the results by individual class. This chart shows that there has been good consistency between classes. Class 7 (marked with the arrow) is the at-risk, middle-school class from La Academia de Esperanza (see following
Fig. 11. Pre/Post-Test PETES PRS Gains Per Student

Fig. 12. Pre/Post-Test Systems Engineering Gains Per Student

It was gratifying to see that the pre/post-test score improvement shown by these students compared favorably with the improvement shown by the other classes.
Pre/Post tests for the PETES PRS Flight and the Systems Engineer Flight in Fig. 11 show impressive gains especially since in these two Flights, the students come out for only 3 days of instruction over the course of the entire school year. As seen in these graphs, the mean gain for the PRS Flight was a phenomenal 18.2 percent, and again showing the greatest gains by those students with the lowest pre-test score. The gains in the Systems Engineering Flight shown in Fig. 12 show a 17.3 percent gain. Both of these Flights are tied to the R&D activities of the KAFB and reflect the impact of having S&Es with real-world experiences mentoring the students and in assisting in the design of the curriculum. Both of these Flights also showed consistency in post-test gains across the different classes and schools.

*Longitudinal Studies* – Since its inception in 1992, the La Luz Academy has grown steadily (see Fig. 13) and in 2008-2009 reached a cumulative total of 32,050 students. We believe both in terms of the number of students enrolled and in terms of the length of time that the program has been in operation that it is appropriate to determine whether or not this program has had a long-term impact on the career paths of students involved. This is a complex issue since we are not only interested in where students go after they leave high school, but where they end up working 6 to 10 years after graduation from high school. Since this is an economics issue more than an education issues, we have asked the Eastern New Mexico University to help. They have designed survey instruments for this study. The initial survey will cover the largest school district in NM, the Albuquerque Public Schools.

**An Important Note** – One of the key attributes of the AFRL La Luz Academy is its success at inclusion. All of our Flights are open to all students from those at risk to those attending private schools. The success that the AFRL La Luz Academy has had in recruiting students from at risk schools including alternative schools is remarkable. For example, last year, students from a public charter school, La Academia de Esperanza (The Academy of Hope), designed and built a submersible robot to take water samples of their research water pond, feed the fish and take under water pictures. What is unique about their success is their previous problems in traditional schools. These students have been expelled from their regular schools and are attending this school as their last hope.

**Conclusions**

The commitment to STEM outreach is a reflection of the Air Force mission statement. These two programs provide a glimpse into this commitment and also the creative ways in which the Air Force, in conjunction with the NDEP, is reaching K-12 students to supply its future S&E
workforce needs and to meet the challenge of maintaining the Air Force as the predominant air
and space warfighter in the world.

When reflecting on results such as these, one can question whether the improvements are due to
the actual classroom experience or whether the improvements occurred because of external
activities, either in their individual schools or through students participating in other STEM
related outreach programs. This is particularly true for the DoD STARBASE data since the
students in this program come out for 5 non-consecutive days during the course of the entire
school year and thus there is a significant time lapse between the pre-test and the post-test
administrations. Assigning causality is always an issue in such assessments, but we earnestly
believe that we have made a difference.