AC 2009-1580: THE PREENGINEERING PROGRAM INITIATIVE OF THE NATIONAL DEFENSE EDUCATION PROGRAM: A NAVY FOCUS

Eugene Brown, Virginia Tech

Eugene Brown is Professor of Mechanical Engineering at Virginia Tech. He has worked with ONR and DoD since 2001 on educational-outreach-related work-force development issues. He teaches undergraduate and graduate courses in thermodynamics and fluid mechanics and is the author of many papers and reports describing his research in the areas of computational fluid dynamics, fluid mechanics and his work in educational outreach.

Robert McGahern, DDR&E

Robert McGahern is the Director of the National Defense Education Program (NDEP) Pre-Engineering Partnerships (PEP) initiative for the Office of the Director, Defense Research and Engineering (DDR&E). Prior to his current position Mr. McGahern served as Deputy Director of the N-STAR initiative at the Office of Naval Research.

Robert Stiegler, NSWC-DD

Robert Stiegler is currently supporting the USMC Targeting and Engagement Systems and the K-12 Outreach Programs for the DDR&E National Defense Education Program, Office of Naval Research N-STAR initiative, and the Naval Sea Systems Command Outreach Program. He previously served as a program manager for USMC science and technology programs, Science Advisor to the Commanding General, Fleet Marine Forces Atlantic, and Head, NAVSEA Combat Systems Safety and Engineering Division.

The Pre-Engineering Program Initiative of the National Defense Education Program—A Navy Focus

Abstract

Through the Pre-Engineering Program (PEP) initiative, a part of the National Defense Education Program (NDEP), the Department of Defense (DoD) is mounting a nation-wide effort to assure the viability of the nation's future scientific and engineering workforce. Building on lessons learned from the Navy-supported Virginia Demonstration Project (VDP) begun in 2001, the PEP will grow to reach from coast to coast in 2010 when 20 Navy, Army, and Air Force research centers and their surrounding school districts will be a part of the program. This paper will focus on the Navy component of this program.

Background

The National Defense Education Program (NDEP) is building a foundation for the future workforce needs of the Department of Defense (DoD) by supporting science and math programs at the pre-college, undergraduate/graduate, and faculty/post-doctoral levels. At the K-12 (pre-college) level, NDEP's Pre-Engineering Program(PEP) initiative features both 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. For college and university students, NDEP supports basic and applied research opportunities through the SMART (Science, Mathematics, and Research for Transformation) scholarship program strengthened through summer internship work experiences. At the faculty/post-doctoral level, NDEP provides significant funding for basic research through the National Security Science and Engineering Faculty Fellowship (NSSEFF) program.

NDEP is a 21st century update to the National Defense Education Act (NDEA) which Congress enacted in 1958 to reorder the perceived advantage that the Soviet Union seized when it launched Sputnik into space. The NDEA authorized a far-sighted investment in science, engineering, and math education that produced the vaunted "rocket science" generation that came to work for the federal government beginning in the 1960s and secured the technological superiority of the United States during the latter part of the 20th century.

America was once again shocked into reassessing the adequacy of our future science and engineering (S&E) workforce after the September 11, 2001 terrorist attacks. That self-examination, and the need to put more people to work on technical solutions to the problems of terrorism, war, and national security, led Congress to authorize the Department of Defense to create the SMART (Science, Mathematics, and Research for Transformation) pilot program under the Ronald W. Reagan National Defense Authorization Act (NDAA) for Fiscal Year 2005. The immediate positive response to the SMART program prompted Congress to make SMART permanent and lay the foundation for a National Defense Education Program that would support the development of a new generation of scientists and engineers who will put their human capital resource talents to use in our nation's defense laboratories.

In the words of Dr. William S. Rees Jr., former Deputy Under Secretary of Defense (Laboratories and Basic Sciences): "We don't own the problem of American education in science and technology, but we have to be part of the solution. The technological superiority that our country enjoys today is something we inherited from those who invested in research and education in the 1960s and 1970s and it is something we now owe our children and our children's children."

More about Motivation

Spending $1.7 billion on basic research, the U.S. Department of Defense operates more than 50 Navy, Army, and Air Force laboratories that, combined, are the largest employer of scientists and engineers in the nation. The Department of Defense, the largest pure research organization in the world, employs about 99,000 scientists and engineers with nearly 75 percent working as engineers. Strategically situated in nearly two dozen states, these labs are the premier place in the world for fostering scientific breakthroughs. Scientists, engineers, mathematicians and others working in these locations have freedom to pursue unexpected paths opened by new insights.

Fig. 1. The NDEP Logo

Fig. 2. NDEP Participating Navy Laboratories

A few selected facts about each trend make clear the urgent need for the NDEP program:

• **Shrinkage of the DoD S&E workforce through attrition and retirement**
The DoD S&E workforce declined by 38 percent, from 45,000 to 28,000 between 1990 and 2000, even before the peak of the retirement wave that is currently depleting our defense laboratories of their most seasoned scientists and engineers. The DoD is facing a stark reality: its Apollo generation is ripe for retirement. Budget cutbacks and ongoing constraints in funding for basic research and other program categories have prevented hiring from keeping pace with separations which are anticipated to amount to more than 13,000 scientists and engineers in the next decade.

• **Shortage of U.S. citizens with S&E degrees**
Several reports have warned of a drastic shortage of high-quality degree holders in the defense-related S&E disciplines who are U.S. citizens (that is, eligible for security clearances). In 2006, the American Society for Engineering Education reports that 61.7

percent of the engineering doctorates awarded in the United States went to non-citizens. This is a 3.8 percent increase over the year before.

• Competition with private industry
The fewer number of S&E graduates coming out of U.S. colleges and universities are enjoying stiff competition for their talents from private industry. The Bureau of Labor Statistics projects a 30 percent growth in demand for scientists and engineers across the U.S. economy by 2010. This trend, coupled with the dwindling supply of U.S. citizens with advanced S&E degrees, means that our defense laboratories are facing increasing difficulties attracting top-of-the-class talent in defense-related leadership positions.

• Global competition for talent
At the same time, foreign universities are graduating scientists and engineers in greater numbers, and foreign nations are accelerating their investments in S&E fields, foreshadowing European and Asian scientific and technological parity with the United States. DoD laboratories and U.S. defense companies may soon, for the first time, have to compete with foreign entities and offshore U.S. commercial companies for the top American scientists and engineers.

The NDEP Components

NDEP's purpose is to foster a new generation of scientists, mathematicians, engineers and technologists who will one day discover and problem solve in the nation's defense laboratories. It is the first comprehensive effort by the DoD to step forward with funding and grassroots participation by its own technical workforce. The effort is aimed squarely at nurturing both leading-edge research for today and developing future lab scientists and engineers for tomorrow.

The NDEP is configured to support defense-related STEM (science, technology, engineering, and mathematics) learning and teaching across three broad phases of the educational spectrum: pre-college, undergraduate/graduate, and post-graduate/faculty. What follows is a summary of the current NDEP portfolio components. NDEP has been designed to accommodate additional program components as demonstrated needs arise.

I. Pre-Engineering Program(PEP) initiative
The Pre-Engineering Program(PEP) initiative of the NDEP covers the pre-college years, primarily middle school and high school when children explore and lay the groundwork for their future academic and employment experiences. Research has shown that middle school is an especially pivotal time when many children set aside their curiosity about the natural world and develop a perceived aversion to math and science.

II. Undergraduate/Graduate Phase
The second portion of the NDEP spectrum is very broad and covers everything from community colleges (associate degrees), four-year colleges and universities (bachelor's and master's degrees), all the way through doctoral degree programs. Through financial support and mentoring programs, NDEP attracts the best STEM-degree-seeking college and university students. Currently, the NDEP portfolio supports the needs of this group

with our most mature — but still very new and already very successful program; The Science, Mathematics, and Research for Transformation (SMART) scholarship program

III. Postgraduate/Faculty Phase
By engaging top-notch faculty in research and problem-solving in areas critical to America's defense and national security, this third portion of the NDEP spectrum taps the best research talent residing within academia. In turn, these faculty come in contact with hundreds of students and can engage them in supported research projects and introduce them to contacts and potential careers in our defense laboratories. Currently, this phase of the NDEP Program consists of a new fellowship program--the National Security Science and Engineering Faculty Fellowship (NSSEFF) program.

The Pre-Engineering Program (PEP) Initiative

Overall, the PEP seeks to increase the interest of K-12 students in pursuing careers in science and engineering. There are two categories of programs within the PEP initiative. The first category is enrichment programs where the PEP steps in to provide additional support for existing after-school or summer school programs. The objective of such programs is to increase student interest in mathematics and science in general. The second category is curricular-change programs which seek to effect in-school changes by promoting the use of problem-based learning methods to enhance the way science and math are taught. The objective of such programs is not only to increase student interest in mathematics and science, but to increase student level of knowledge in these topics and to provide a positive impact in the way these subjects are taught.

Enrichment Programs

In its search for existing programs, the PEP seeks tools which emphasize the use of mathematics at the middle-school level in the form of a robust library of pre-engineering curriculum materials and resources that capture and hold young people's interest in science, math, and technology. These programs are incubators for new concepts and ideas to make math and science learning interesting and relevant to today's youth. Some of these programs have a national reach that allows the NDEP to quickly bring the best of available programs to a large and diverse population of students. Examples of non-DoD nation-wide programs which PEP is currently supporting include MATHCOUNTS® and the Center for Excellence in Education's Research Science Institute at MIT. Programs in which the Navy is involved include:

- St. Mary's Academy Internship Program (SSCSD) – Through a partnership among St. Mary's Academy, the Office of Naval Research, Space and Naval Warfare Systems Center, San Diego, and Submarine Base Point Loma, ten girls and two teachers had the opportunity to attend in-house seminars, an unmanned underwater vehicles competition, and off-site tours (navy ship, local universities, etc.) at Port Loma. Each intern was assigned DoD S&E mentors, and over their month-long internship they kept a journal on their projects and presented their results to Navy management as well as to their peers back at school.

- Taku Marine Science Camp (NSWCDD and NUWC-Newport) – The Taku camp exposed local students to scientific terminology and research methods as they examined the marine ecosystem in the vicinity of Juneau, Alaska. Activities included boat trips on which marine mammals were observed and hydrophones were used to record underwater life in various ocean habitats. Daily activities included GPS mapping, trawl dragging of the ocean floor and plankton net towing, microscopic identification of marine specimens, seafloor mapping, and fish surveys. Navy civilian researchers traveled to Alaska to serve as mentors and special guest speakers.

- Science and Engineering Apprentice Program SEAP (ONR) – The Science and Engineering Apprentice Program provides an opportunity for high-school students to participate in research at a Navy laboratory during the summer. The goals of SEAP are to encourage participating students to pursue science and engineering careers, to further their education via mentoring by laboratory personnel and their participation in research, and to make them aware of research and technology efforts, which can lead to employment within the Navy. Participating students spend eight weeks during the summer doing research at approximately 15 Navy laboratories.

- Save the Bay (NSWCIH) — Charles and St. Mary's (MD) county's 5th, 7th, and 9th grade teachers and students, mentored by the Navy's Indian Head S&Es and College of Southern Maryland students, work with robotics and conduct environmental research to understand the problems and solutions in the Chesapeake Bay. Each student will participate in a 16-week, in-school program and a week-long, all-day summer camp. There are currently 400 participants in the program.

Curricular-Change Programs

The majority of PEP's efforts are absorbed in a second set of programs which offer hands-on, math-based, in-class learning experiences and seek thereby to strengthen the STEM-teaching skills of the teachers involved. In these programs, teachers and DoD S&Es work together to bring compelling and engaging science and math instruction into the classroom. Students explore the world around them in an inquiry-based laboratory setting and experience first-hand some of the excitement that a career in the sciences delivers. The student interactions and learning materials are inquiry-based and are in direct alignment with national and state educational standards.

Operationally, these DoD mentored activities:

- Are primarily classroom centered.
- Bring the professionals into personal contact with students and teachers.
- Make math and science cool.
- Serve students in classroom-sized groups.
- Are inquiry-based learning with no predetermined right or wrong decisions.

The heart of and inspiration for this set of programs is the Virginia Demonstration Program (VDP). The goal of the VDP is:

"To assist in the development of the future science and engineering workforce of the nation and thereby contribute to both national security and competitiveness by increasing the numbers of domestic students (particularly students from under-represented groups) pursing higher education in science, technology, engineering, and mathematics by enhancing student interest and attitudes toward math, science, technology, and engineering; strengthening peer, family, and school support for such interests; ensuring long-term inclusiveness of women and minorities in science and technology programs; and increasing the numbers of K-12 students taking advanced-level mathematics and science courses."

The VDP is an Office of Naval Research sponsored, mentor-based, educational outreach program that uses Navy scientists and engineers working alongside teachers in the classroom to increase the level of interest among middle-school children in pursuing careers in science and engineering. By the end of the 2006-2007 school year, 3042 students, 86 teachers and 48 scientists and engineers had participated in the VDP. Fifty school counselors had participated in the counselor education programs and ten different sets of professional development training activities were provided to professional co-teaching teams. Seventh and eighth graders in the public school systems in three Virginia counties immediately surrounding the Naval Surface Warfare Center, Dahlgren, were involved. These were Stafford, King George, and Spotsylvania counties.

The VDP has both an in-school and a summer school component. Forming the heart of the in-class component were Robotic Challenges that required the solution of problems having both a societal and Navy focus using LEGO MINDSTORMS equipment. The summer school component features advanced robotics challenges and specially-constructed breakout experiments, which were used to illustrate specific mathematics and science topics.

Fig. 3. VDP Summer Camp

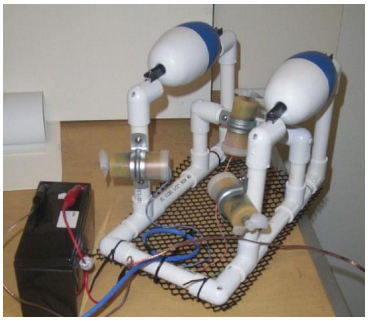


Fig. 4. A Sea Perch Vehicle

Faculty from the School of Education of the College of William and Mary provide professional development workshops on co-teaching, structuring and leading cooperative learning groups, and curricular connections for the robotics scenarios in the form of comprehensive lesson plans. With the help of the Navy mentors, faculty from William & Mary train the teachers in the use of the LEGO MINDSTORMS kits and ROBOLAB software, which are the focus in much of the classroom and summer camp activities. The idea is to prepare classroom teachers and DoD

professionals to provide hands-on instruction to middle school students under their expert guidance, through trial and error, just like real lab scientists.

Central to the classroom and summer camp components of the VDP is the utilization of Navy Scientists and Engineers (S&Es) as mentors working along side middle-school teachers to enhance science and mathematics instruction using the methods of problem-based learning and the infusion of real-life examples of the application of science and math concepts obtained from the professional experiences of the DoD technical personnel involved. Experience has shown that learning science and mathematics can be fun and exciting for students when teachers partner with scientists and engineers from the civilian defense community to explore learning concepts in the classroom. This initiative has enormous potential in its ability to positively influence the students' impression of science and mathematics at a critical point in their academic careers and to deliver exciting programs in the classroom and make the study of science and math more rewarding for today's youth.

Similar in motivation and structure to the VDP but involving under-sea, rather than land vehicles, is the Sea Perch program, Giver (1). Begun at MIT and now supported in part by the PEP initiative, Sea Perch, just like the VDP, is used to inform and educate students through hands-on activities, with the objective of generating interest and enthusiasm for science, technology, and engineering studies. Sea Perch is a kit consisting of PVC pipe, wire, small motors, film canisters, wax, switches, small propellers, and other items that allows students to construct a simple, remotely-operated underwater vehicle from PVC pipe and other readily available materials. Giver remarks: "The students have fun without realizing how much they are learning." The program culminates with a Sea Perch Challenge which puts the students' Sea Perch vehicles and their teamwork to the test as they participate in performance competitions and compete for awards and prizes.

In order to facilitate the use of Sea Perch in the classroom, connections have been made between the program and seven of the eight elements of the 9-12 grade level National Science Education Standards (2). One of the unique aspects of the program is the teacher training. Teachers participate in a two-day training program in which they interact with naval engineers, learn how to build a SEAPerch vehicle, and are given access to in-school curricular materials to complement the program consisting of lesson plans on basic construction skills, the operation of motors, depth measurements, and optical principles.

Naval engineers also act as mentors in the classroom guiding the students in the construction and testing of their vehicles and simultaneously giving the students a perception what it is like to be a naval engineer. The mentoring continues in the form of student visits to Navy labs and visits that the naval engineers make to Sea Perch schools for career day presentations. Sea Perch has reached over 2,000 students and nearly 100 teachers in the past year alone. Initially the project was focused in the Washington, DC, Virginia, and Maryland areas; however, with a grant provided by the Office of Naval Research to the Society of Naval Architects and Marine Engineers plans are in place to expand the program on a national level within the next five years.

The Materials World Modules (MWM) program is similar to Sea Perch in that it was originally developed without the DoD in mind. Like Sea Perch it has a teacher training component. MWM

is a kit-based program developed at Northwestern University under a grant awarded by the National Science Foundation in the late 1990s. These modules represent short-duration high and middle school-level material science coursework that combines inquiry and data collection with team-based design of composites, concrete, food packaging, smart sensors, and materials science content.

A variety of MWM learning modules are available, such as robotics, sports materials, and biosensors and new learning modules that focus on other aspects of the STEM disciplines are under development. With NDEP support, MWM professional development summer workshops are held to introduce teachers to the modules and the inquiry and design teaching process instruction is provided by the College of William and Mary. DoD S&Es have recently been added to the program to work as mentors in the classroom beside the teachers in a fashion similar to the VDP. It is planned to disseminate the MWM in nine states during FY08-09, using Army, Air Force, and Navy laboratories as hubs for kit distribution and local partnerships.

Assessing the Effectiveness of the Curricular-Change Programs

Due to the significant investment in funds in the curricular-change programs, vigorous and comprehensive assessment programs are essential in both determining their effectiveness and in identifying and guiding needed improvements.

VDP

Assessments of the VDP revealed enhanced attitudinal changes among students in pursuing careers in science and engineering as a result of participating in the program. Results show a 7% to 19% gain in student reported probability of choosing a STEM career. In addition, as shown in Fig. 5, in pre- and post-testing the results show a 20.4% increase in student-reported knowledge of what scientists do, a 22.4% increase in knowledge of what engineers do, and a 30.2% increase in what Navy scientists and engineers do. Even more significantly, as shown in Fig. 6, in a county (King George) where 7th and 8th grade performance on the state-mandated Standard of Learning (SOL) tests failed to meet the acceptable level in mathematics in 2005-06, one year after VDP was implemented in the school system the passing rate increased to 53% in the 7th grade and 82% in the 8th grade—a 65% and 21% increase from the previous year.

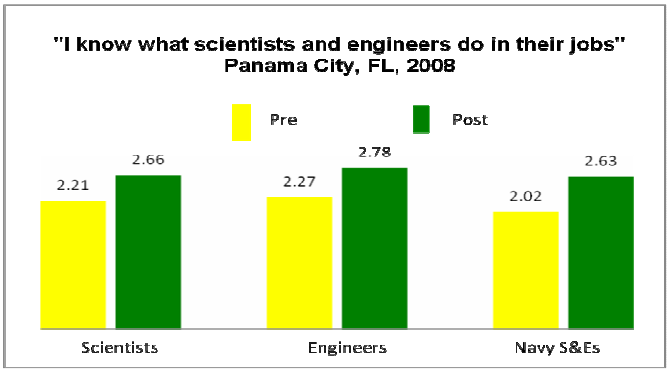


Fig. 5. VDP Career Knowledge Gains

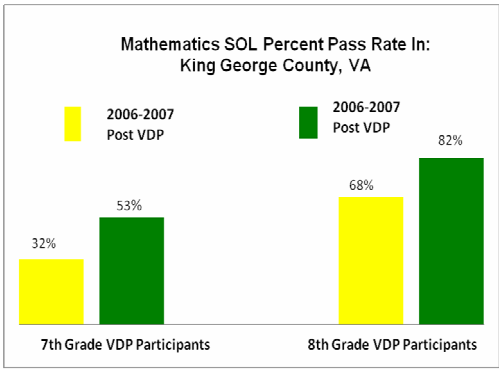
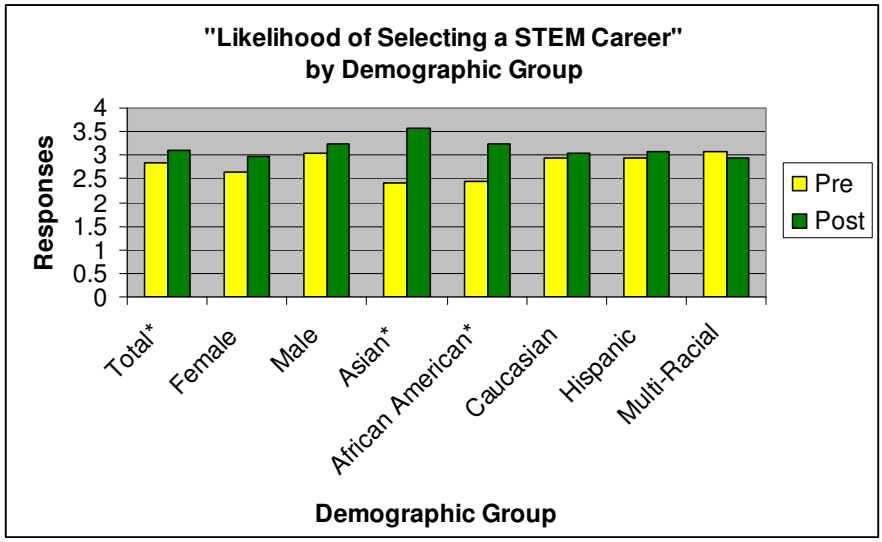


Fig. 6. VDP Change in SOL Pass Rate

More recently acquired data provides further indication effect that VDP has had on increasing the attractiveness of pursuing STEM careers. Fig. 7 provides the results of an assessment made in the fall of 2008 of the interest in pursuing careers in the STEM disciplines of 426, 8th grade students in Stafford County (VA). The scale of the responses ranges from 1 = Strongly Disagree to 4 = Strongly Agree. In seven of the eight results shown in Fig. 7, there is an increase in post-test likelihood of pursuing a STEM career over the pre-test results. The asterisks on the Total, Asian, and African American results indicate that they are statistically significant at a level of 95% probability. It is encouraging to see that the there is an overall (Total) pre-post increase in of 9.9 percent and that the pre-post increase for African Americans (32.8 percent) is the second highest of any demographic group. It is also encouraging to see that the percentage pre-post increase of females is more than double that of males.



Admin.	Total Group	Female	Male	Asian	Black	Caucasian	Hispanic	Multi-racial
Pre	257	137	120	13	46	130	24	33
Post	169	85	84	9	25	93	12	23

Fig. 7. Likelihood of Pursuing a STEM Career. VDP, Stafford Co, VA, Fall 2008.

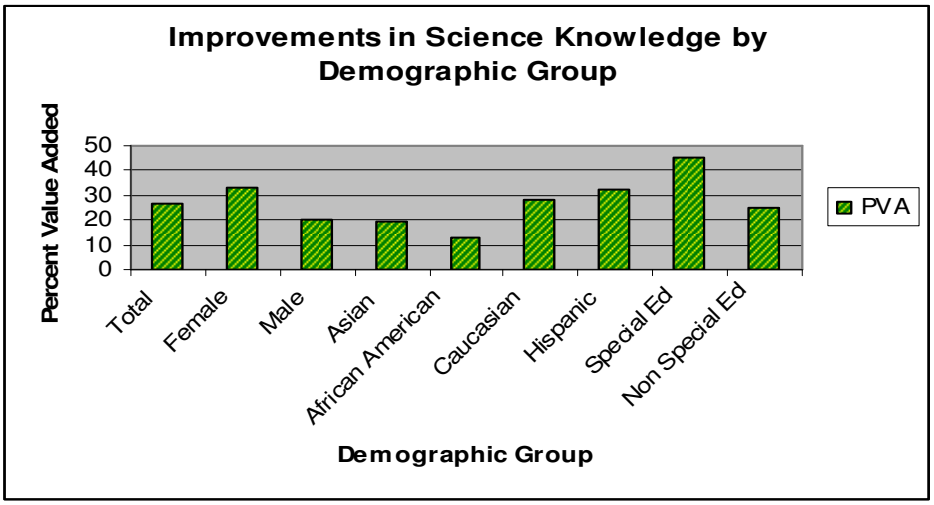
Sea Perch

Pre-Post testing of the students currently enrolled in the Sea Perch program managed by NSWC Carderock Division is underway and will be available by the time this paper is presented. At the moment only anecdotal information is available. The results look encouraging.

MWM

In May and June 2008, pre- and post-testing of 533, 8th grade students in two Harford (MD) middle schools was conducted to determine the effectiveness of employing the Sports Materials module of the MWM. Fig. 8 shows the results. Percent Value Added is computed by taking the

difference between the post-test scores and the pre-test scores and dividing by the pre-test scores. The results are striking. Science knowledge gains were greater for Females than Males, and greater for Hispanic and Special Ed students than for the students overall (Total).



Female	Male	Asian	Black	Caucasian	Hispanic	Multi-racial	Spec. Educ.
50%	50%	4%	6%	84%	4%	4%	9%

Fig. 8. Increase in Science Knowledge. MWM, Harford Co, MD, Spring 2008

Expanding the PEP

The enrichment and curriculum change activities of the PEP will be in 12 states by the end of 2008 and 20 states by the end of 2010. Just last year, the VDP and MWM summer camps were expanded from Virginia and Maryland to include Florida and California, and teacher training sessions were conducted with teachers/teams from Alaska, Hawaii, New Jersey, New York, South Carolina, Alabama, Pennsylvania, and New Mexico.

Where To Go for More Information

NDEP recently announced the launching of a comprehensive website "NDEP—Building American Strength in Science and Engineering" directed at teachers, mentors (S&Es), students, the local defense community, parents, guidance counselors, and administrators. It can be found at http://www.ndep.us. There detailed information on and useful links to all of the programs of the NDEP can be found along with information about student competitions and awards for teachers. Compelling personal histories of DoD scientists and engineers can be found there including what peaked their interest in science and math. An interactive map with information about the activities of all DoD labs can be found there as well as testimony from DoD S&Es who have served as mentors in the program. A useful FAQ page can also be found there as well as links to the NDEP newsletter, STARLink.

Perhaps the most outstanding feature of the website is an initiative called LabTV, a weekly series of on-line laboratory science and math videos designed to showcase for middle-school students the research being done at DoD laboratories. Most of the LabTV "webisodes" are filmed on-site at Army, Navy, or Air Force laboratories. These videos are meant to stimulate student interest in science and mathematics and show that, not only is science and math cool, kids can pursue future career opportunities within DoD if they are so inclined. They bring both the science and the technologists themselves within perceptual reach of these young adults and leave them with a lasting sense of "that is really cool" and "I want to be, and I could be, one of them".

Beyond the NDEP—A New Navy Initiative

Just as the NDEP is addressing the future S&E workforce needs of the DoD, the Navy is looking to its future by establishing the 21st Century Engagement, Education, and Technology Program (21CEETP). An important component of this program is the implementation of a middle-school outreach effort modeled after the VDP. In the words of Joe Coleman, Naval Sea Systems Command (NAVSEA) Element 1 Program Lead: "VDP will be leveraged as a corporate tactic for scholastic engineering development in support of the NAVSEA strategic plan."

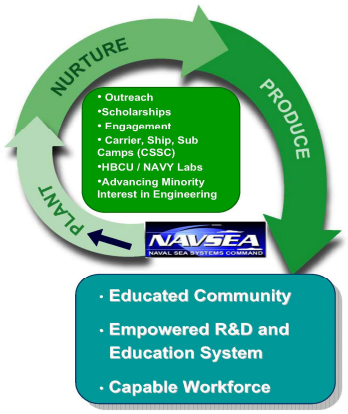


Fig 9. The 21CEETP Concept

When fully implemented, the 21CEETP will involve all nine of NAVSEA's warfare centers and all four of its shipyards. NAVSEA's 21CEETP is a comprehensive workforce development program with a STEM focus that has a K-12 component which mirrors many of the feature of the VDP, an undergraduate scholarship component, and a post-graduate component in which young engineers and scientists involved in 21CEETP-supported university research will be recruited into the Naval Systems Commands (SYSCOMS) workforce. The three components (elements) of the 21CEETP are as follows:

- PLANT (K-12 Element): Engage in scholastic engineering development programs that will bring students (elementary and high school level), educators, SYSCOMS professionals and community leadership into partnerships that will promote STEM interest with the objectives of: 1) generating and sustaining excitement for STEM education and careers, 2) invigorating middle-school and

high-school science and math curricula, and 3) enhancing science and math training for teachers.

- NURTURE (Undergraduate Element): Provide scholarship and mentorship to engineering college students as encouragement for their continued academic pursuits. The initial NAVSEA efforts will be toward Historically Black Colleges and Universities (HBCU) with accredited engineering degree programs with the objectives of: 1) establishing a long term program to create scholarship opportunities for college students to pursue degrees in STEM-related fields, and 2) creating opportunities for STEM internships at SYSCOMS facilities.

- PRODUCE (Post-Graduate Element): Invest research and development funds to the sponsored Universities, to conduct "relative research" efforts for NAVSEA and other SYSCOMS and actively recruit the STEM graduates into the NAVSEA workforce with the objectives of: 1) establishing long term relationships with college and university departments and faculty to continue research and engineering work, and 2) regularly interacting with scholarship students to encourage future employment within the Naval Enterprise.

The goal is to implement the three elements noted above in FY2010.

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