Learning by Doing—Hands-On Experiments for a Middle-School Outreach Program

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Abstract - A middle school outreach program funded by the Office of Naval Research is described which has the goal of increasing the number of US students enrolling in and graduating from degree programs in science and engineering. Scientists and engineers from the Naval Surface Weapons Center in Dahlgren, Virginia, work as mentors and role models in seventh-grade classrooms in local middle schools alongside the regular teachers in a co-teaching environment. Problem-based learning is used to supplement the regular instruction, provides real-life illustrations of the type of work these scientists and engineers do, and builds interest and develops problem solving skills among the students. Evaluations show that this approach has promise. Plans for extending and expanding the program are underway.

Keywords: Middle school, problem-based learning, outreach.

BACKGROUND

“Few would disagree that the challenge of recruiting more students into science and engineering careers begins in the K–12 education system. Efforts by schools to bolster math and science education will be more effective if they are supplemented by public–private efforts to give students exposure to scientists and engineers. Students should have opportunities to participate in programs that help them see the wide range of career options open to them if they have a strong foundation in science and math.” [1]

Many statements like this are coming from public and private groups pointing to the need to address a shortfall in the number of US students pursuing careers in science and engineering if the Nation’s economic vitality, and military security, and personal standard of living are to be maintained. Recent publications alerting the Nation to this issue have included the National Academy of Engineering’s Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future [2], the National Defense University’s “Science and Engineering Workforce and National Security [3],” the Task Force on the Future of American Innovation’s The Knowledge Economy: Is the United States Losing Its Competitive Edge? [4], and the US Chamber of Commerce’s Tapping America’s Potential—The Education for Innovation Initiative [5]. In response to this situation have come reports for

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educational reform such as the National Academy of Engineering’s *Educating the Engineer of 2020: Adapting Engineering Education to the New Century* [6], the National Academy of Engineering’s *The Engineer of 2020: Visions of Engineering in the New Century* [7], the Business-Higher Education Forum’s *A Commitment to America’s Future: Responding to the Crisis in Mathematics and Science Education* [8], and critical explorations of the effectiveness of the Government’s efforts at encouraging students to enter mathematics and engineering programs such as the General Accounting Office’s *Federal Science, Technology, Engineering, and Mathematics Programs and Related Trends* [9]. Hardly a day goes by without articles such as the Wall Street Journal’s “America Gasps For Breath in the R&D Marathon” [10] greeting us over our morning coffee.

An additional indication of the seriousness of the situation comes from the National Opinion Research Center’s (2005) *Survey of Earned Doctorates* [11]. The data shows that over the past 10 years there has been a 24 percent drop in the number of US citizens earning PhDs in the physical sciences (including computer science) and a 22 percent drop in the number of US citizens earning PhDs in engineering. In addition, and particularly relevant for the program which we will describe here, there has been a steady decline in interest among physical science and engineering PhD graduates in considering the Federal government as a future employer.

**THE VIRGINIA DEMONSTRATION PROJECT**

In 2002, Admiral Jay M. Cohen, DoN’s Chief of Naval Research, and the leadership of the Naval Warfare Centers (NWCs), comprising the Naval Surface Warfare Center, the Naval Undersea Warfare Center, the Naval Air Warfare Center, and the Space Naval Warfare Systems Command, launched the Naval Research-Science and Technology for America’s Readiness (N-STAR) program. This program has the goal of creating the intellectual capital base needed to develop the technology options for the “Navy-After-Next.”

Funded through the Office of Naval Research (ONR), N-STAR has begun to develop an integrated continuum of activities and programs that have as their ultimate goal recruiting 500 new scientists and engineers per year over the next ten years into the Naval Research Enterprise (NRE) which comprises the NWCs plus the Naval Research Laboratory.

![Figure 1: VDP Academic Year Program](image1.jpg)

![Figure 2: VDP Summer Camp](image2.jpg)
In 2004, in response to interest expressed by the Commonwealth of Virginia, the Virginia Demonstration Project (VDP) was added to the N-STAR program. The VDP is an outreach program currently being piloted in the counties near the Naval Surface Weapons Center Dahlgren Division (NSWDD). The VDP uses carefully selected scientists and engineers at the Center as mentors and role models in the classroom working alongside teachers in a co-teaching mode, with the goal of increasing the number of US citizens, including those from under-represented groups, enrolling in and graduating from degree programs in science and engineering. For the past two years, funding for the program has been provided in the form of a Congressional appropriation sponsored by Virginia’s Senator John W. Warner.

In 2005, the first year of the program, VDP was piloted in the seventh-grade mathematics and science classrooms of the six middle schools of the Stafford County (VA) Public School system. Directed by RAK (second author of this paper) and co-managed by EFB and RLS, the Virginia Demonstration Project has partnered with the School of Education of the College of William and Mary to develop a hands-on, community-based, interdisciplinary, academic-year and summer camp program. With two additional school systems, additional teachers in Stafford County, and an expansion to include the additional disciplines of language arts and social studies, VDP will reach nearly 2000 students this year.

**Problem-Based Learning**

“Experience to date has shown that students can be attracted to and retained in engineering programs if they are exposed early to the joys of creation through design, discovery through research, and invention through hands-on experimentation.” [12]

Problem-Based Learning (PBL) in the school setting is characterized by having the learning directed by the solution of authentic, open-ended problems in which the learning process becomes student-centered and not teacher-centered. Greenwald [13] described PBL as a shift in the roles for students and teacher. In PBL, the teacher raises questions and shapes the learning experience so that the student is motivated to work through the processes necessary to find possible solutions to the problem. PBL in the school environment is designed to approximate conditions where engineers, scientists, and all professionals work; that is, PBL in school settings is designed to be collaborative, self-directed, and authentic.

Gallagher et al. [14] pointed out that PBL usually involves situations where students realize there is no single right answer or solution, as well as situations where students are unsure about their solutions because there is not enough information available. Implementation of a well-planned PBL curriculum increases all students' abilities to solve problems and work as a member of a team, and thus has the potential to increase the number of females and minorities who consider mathematics, science, and engineering as possible careers. An additional aspect of PBL curricula that impacts females and minorities is the examination of real-world benefits of solving the problem. Such connections provide a context and a reason for learning theories and facts that connects science to students' lives and suggests possible careers in science. See Baker [15].

In the present high-stakes assessment environment in public education, it takes courage and support for a teacher to be willing to implement a PBL curriculum, since failure could have many negative consequences. Introducing PBL in the classroom therefore has two primary challenges: 1) the development of a curriculum focused on the solution of problems as the objective, and 2) the development of a pedagogy of facilitation where student-directed learning is encouraged and problem solving skills are developed. Neither of these comes easily, which is why professional development workshops for the teachers and the Navy mentors formed such a critical part of the project.

In VDP’s first year, the use of PBL was supported by Stafford County’s choice of a standards-based elementary mathematics textbook series which focuses on problem-based learning and concept building. The professional discussions with the VDP staff provided support for the curriculum and textbook adoption process in focusing on the elementary and middle school mathematics concept-building connection.
CHOICE OF THE PROBLEMS

There were two types of problems used in the VDP: 1) Robotics Challenges, which required the solution of problems having both a societal and Navy focus using LEGO Mindstorms and were used in both the academic year and the summer camp programs and 2) Breakout Experiments, which were used in the summer camp program to illustrate various specific mathematics and science topics.

Robotics Challenges

The activities of the FIRST LEGO League (FLL), a highly-successful program which operates robotics competitions both throughout the US and internationally, was the inspiration for this part of the program. This led to the decision to use the LEGO Mindstorms kits and the ROBOLAB programming language.

The next question was: “What do we do with the kits?” Despite the fact that we had an ONR mandate to include a Navy Research Enterprise focus in the project, the VDP project managers and engineers as well as the Stafford County school administrators and teachers felt that it would be beneficial if the challenges focused on societal rather than military needs to maximize the appeal of the challenges, especially to girls.
In search of a compromise, we looked into the Navy’s view of their future technological needs as contained in the ONR/Navy Future Naval Capabilities (FNCs) document, http://www.onr.navy.mil/fncs/, and found a topic that appeared promising—Autonomous Operations—which describes the need for the development of uninhabited vehicle and autonomous systems. This robotic focus was a natural fit for the Mindstorms kits.

What to do with the autonomous vehicles was the next question. After much discussion it was decided to develop a challenge around using robotics in a mine-clearing, rescue, retrieval, and construction operation. This, in addition, tied in well with the Littoral Combat / Power Projection and Organic Mine Countermeasures FNCs which involve mine countermeasures, sea basing, and environmental awareness as enabling capability requirements.

The societal connection was provided by the humanitarian aspects of the (then current) news of the tragedy of the tsunami in Southeast Asia which required the location and retrieval of land and sea mines that were scattered by the event. The establishment of a base of operations and the rescue of a damaged submarine and stranded persons at sea were included in the overall challenge.

Student teams also completed an assignment that brought a societal focus, providing coherence and a real-world context to the robotic challenges. Using information on landmines throughout the world, especially taking advantage of information made available through the United Nations (http://www.mineaction.org) the student teams researched countries where un-detonated landmines pose a hazard to civilians, especially children. Digital video cameras and iMovie software were used by student teams to create a show about a country of their choosing. Instructional technology specialists and classroom teachers in the school division supported student teams in learning how to use the digital video cameras and movie-making software. The teams also created poster presentations on their country of choice, where they posted information on the number and type of landmines in that country, the reason landmines were a problem in that country, the potential cost of removal, and recommendations for action.

In the second year of the project, seeking a project that was more life science oriented, we developed the Grounded Oil Tanker Robotics Challenge that involves the containment of marine animal injury resulting from the oil spill produced by a grounded freighter. This scenario was again inspired by a natural disaster—the recent hurricanes in the Gulf region of the US. (For mat layout see Fig 3.)

A standard mat configuration similar to that used in the FIRST LEGO League (FLL) competitions, see http://www.firstlegoleague.org/default.aspx?pid=15880, was used for the Robotics Challenges. The mat configuration provides adaptability and flexibility for developing variations on existing challenges and developing new challenges over a range of environments. The NSWCDD graphics department developed the mats from a basic PowerPoint design provided by the lead NSWCDD mentors. Once the mat design was finalized, it was sent to a local vendor as a JPG file for reproduction on a vinyl base material.

The size of the challenge board was based on three factors; size, ease of production, and ease of storage. Two basic sizes were chosen: a 3 ft x 6 ft board for classroom use and a 4 ft x 8 ft board for the summer camp. This allowed ample room for the student/teacher/mentor teams to access all parts of the board without crowding. The boards were hinged in the center and provided with carrying straps so that they could be folded in half for ease of transportation and storage. The boards are made of standard hardware materials and wood and were constructed by the NSWCDD machine shop.

This year, JK and one of the Stafford County middle school math teachers developed a comprehensive Student Manual to assist the students in the development of the LEGO programming and building skills necessary to complete the Grounded Oil Tanker Robotics Challenge. Figures 5 and 6 were taken from that manual.

**Breakout Experiments**

Seven additional experiments were developed for the summer camp program. These were the Ball Drop, Paintball (which included high-speed photography), Water Balloon Launch, Electric Gun, Rocket Construction/ Launch, Egg Drop, and Alarm System experiments. These experiments where selected based on our desire to provide a selection of projects that would demonstrate a wide variety of science- and physics-based phenomena, involve appropriate math and problem solving tasks, provide team building opportunities, and be of interest and fun to a diverse group of students.
students both with regard to gender and ability. An additional (and important aspect) was that the experiments needed to exhibit a close connection to the Virginia Standards of Learning (SOL).

The selection of the experiments with the exception of the Egg Drop was based on the work actually performed by the engineers (or based on their experiences) and the criteria of ease of construction, safety, and applicability to the SOL. The final selection process consisted of the engineers and scientists having ad hoc meetings and discussions over a period of a few weeks, selecting the projects, then assembling and testing the them. All experiments were constructed by the engineers and technicians at NSWCDD. The Ball Drop, Electric Gun, Rocket, and Paint Ball experiments were all based on actual Navy programs at the Center. The Balloon Launch was a modified catapult experiment based on a History Channel program seen by one of the engineers. The Alarm System was chosen as a relatively easy-to-construct experiment that had real world application, demonstrated the basic principles of electricity, and had good math content. The Egg Drop Experiment was included because of its high value as a classic team-building task that is also known to generate interest and excitement among the participants.

Last year, RG prepared a comprehensive 2005 Summer Camp Programming Manual which contained a schedule for the summer activities, the description of the summer Robotics Challenge, and the worksheets for the Breakout Experiments. A page from this manual appears in the Appendix of this paper as well as a Summer Camp Diary which provides additional details about the 2005 summer camp Breakout Experiments.

The Breakout Experiments will be revised and new experiments added every year based upon the assessments of the program by the students, teachers, and mentors. As the focus of their Capstone Design course, four mechanical engineering seniors at Virginia Tech, under the direction and supervision of EFB, RLS, RG and JK, are spending the 2005-06 academic year revising two current experiments and designing two new ones for the up-coming VDP summer camp.

**Linkages with Virginia Standards of Learning**

The Virginia Standards of Learning (VA SOL) were recently rated "A" by the Fordham Foundation (2005), and ranked second among all state science standards. In order for school administrators and teachers in Virginia to justify using any problem-based learning curriculum, valid connections must be made to the VA SOL. The VA SOL for mathematics and science were explicitly connected to all the lessons taught in the spring session using the landmine scenario. Correlations were more easily drawn to the SOL for mathematics, with lessons on ratios, space and proportion, and general mathematical problem solving being incorporated into the curriculum. The science SOL for seventh grade, the target grade in spring 2005, is primarily a set of life science standards. For the pilot phase of the NSTAR VDP lessons, the science teachers concentrated on the Investigation SOL standard (LS.1).

**Selection of Teachers and Mentors**

Up to this point, all teachers have volunteered to be a part of the program. Since the beginning of the project, we have grown from twelve 7th grade science and math teachers in the Stafford County public school system to 48 science, math, language arts, and civics teachers in Stafford County, 24 teachers in Spotsylvania County, and four teachers in King George County. This brings the total number of students served from 343 to almost 2000 students. The teachers are paid a modest stipend to participate in the academic year and summer camp portions of the program, and the school system is reimbursed for the cost of the substitute teachers who replace the regular faculty on professional development days related to the project.

There has been a similar growth in the number of the NSWCDD mentors, again all volunteers. Over the past two years, far more than the required numbers of mentors (12 last year and 18 this year) have shown an interest in being a part of the program. We view the interaction of the mentors with the teachers and students to be absolutely critical to the success of the project, and therefore great care was exercised in their selection. Accordingly, the selection of the mentors has proceeded according to an appropriately rigorous process: 1) An announcement requesting applicants for the mentor positions was posted for a two-week period, 2) The applicants were required to submit a formal resume and a short paragraph describing their interest in the program, 3) A formal interview panel was convened that included 4–5 experienced mentors chaired by a senior NSWCDD manager. After the interview, each applicant was rated and ranked by the panel based on his/her responses to the following questions:

1. In your opinion, why do you think kids aren’t pursuing math/science/technology fields today?
2. How would you explain your job to a middle schooler?
3. Do you have any prior experience working with school-age kids? If so, tell us about that experience. Did you work with teachers?
4. Mentors are expected to be experts in programming and in building robots. These are critical elements of the program. Do you have experience with this? If yes, how would you convey this knowledge to teachers and students? If no, are you interested in learning more about this area?
5. A student comes to you saying they programmed their robot to go forward, but it goes backwards instead. What would you say?

The list of applicants with their ranking and any applicable comments are submitted to RLS and NSWCDD’s Director of Science and Technology for final approval.

**PROFESSIONAL DEVELOPMENT WORKSHOPS**

The School of Education of the College of William and Mary directed the professional development workshops and the overall coordination with the county public school systems for the purposes of both training and instructional implementation as well as the evaluation of the overall effectiveness of the program. Education school faculty in science, mathematics, special education, and counseling served as consultants and staff for the project. Their wealth of expertise and their close connections with the Stafford County Public Schools produced a very valuable and productive collaboration.

The teachers and mentors are provided with training both in approaches to using problem-based learning in classrooms and in technical training sessions. They are trained together in order to build both a confident working relationship and to develop as a team that will implement the curriculum in the schools. With the collaboration and participation of the Stafford County instructional supervisor of mathematics and science and her staff of mathematics and science coordinators, the College of William and Mary provided the SET (scientist, engineer, and teachers) teams with professional development sessions in the areas of collaborative teaching, curricula development, rubric development, problem-based learning, student team management, and ethics in the classroom. The technical training sessions included two days of instructions on the LEGO Mindstorms kits and ROBOLAB software. This is done to develop and expand the robotics and other technology skills (e.g., digital video camera) of the teachers and mentors, but it also provides a team building experience and supports an enhanced working relationship between the teachers and the mentors.

In February of 2005, the William and Mary faculty team put together an initial proposal package for the professional development workshop. School division and NSWCDD personnel, along with William and Mary faculty, determined the final program. Introductory sessions that dealt with instructional approaches to problem-based learning were combined with sessions that enabled the SET teams to gain foundational skills in using the LEGO Mindstorms materials. With input from the school division’s technology resource teacher who is assigned to one of the participating schools, later sessions included training in the use of digital video cameras and in developing iMovie sequences from the video generated by the students. In all the sessions, a collaborative approach was emphasized, and instruction was designed to provide opportunities for the SET teams to talk and work extensively with each other. Instructors embedded opportunities for the SET team members to respond to the content of the professional development sessions. One professional development meeting was held at NSWCDD, which familiarized the teachers with the professional environment of the scientist and engineer mentors. This experience also prepared the teams for planning for the summer camp, since the summer camp was held at the base school of the Center.

A portion of each professional development session was devoted to planning for future training and for reflecting on the ongoing process of developing the project. Guided by William and Mary faculty, the teachers, scientists, and engineers developed grading guidelines (rubrics) for the student projects. The grading rubrics addressed completion of the robotics tasks, the landmine research project, and team cooperation. One of these rubrics can be found in the Appendix. The teaching teams participated in planning the counselor and parent workshops that were implemented in the first phase of this project. A substantial portion of the professional development time was dedicated to team planning.

As the spring portion of the project was ending, SET teams, William and Mary faculty, and NSWCDD were gearing
up for the summer camp. Experiences from the spring implementation phase of the project formed a basis for the summer camp. Again, the SET teams and NSWCDD and William and Mary personnel worked together to finalize the summer camp curriculum and schedule. Additional time was allocated for training in advanced robotics, and the participants developed an ethical decision making approach that developed into the summer camp team research project. During the summer camp, occasional, brief, group meetings were held with all instructional and support personnel to discuss how the camp was going and to raise and deal with concerns.

**EVALUATION OUTCOMES**

Key process goals identified in the first year of the program were the professional development of teachers and mentors, the utilization of problem-based modules in the teaching of middle-school-level science and math courses, the design and implementation of an academic summer camp, and the preparation of a handbook documenting these processes to facilitate the dissemination of the program to other sites. Accompanying these process goals were complementary outcome goals which included (1) increasing students’ and teachers’ knowledge, skills, and abilities in mathematics, science, and technology, and (2) increasing students’ interest and enthusiasm in pursuing careers in science, mathematics, and engineering.

As evidenced by the survey questionnaires as well as the teacher/mentor team interviews, all process goals were met or (in the case of the handbook) identified as an ongoing goal for the second year of the program. The most relevant aspects of a more detailed assessment [16] conducted by our external evaluator, Joe Wholey of the University of Southern California, can be summarized as follows. When asked on an end-of-project survey,

1) 83% of the teachers and 75% of the scientists and engineers responded with a 4 or 5 on the 1-5 point Likert Scale (1 = Not at all, 5= To a Great Extent) that professional development sessions and training were helpful in meeting project objectives,

2) Teachers responded with a 4.32 (SD 0.75) that they received appropriate training prior to the initiation of the program and with a 4.36 (SD 0.49) that student Robotics Challenges were effective in meeting project objectives, and

3) 100% of the teacher/mentor teams which participated in the summer camp responded with either a 4 or 5 when asked whether the Robotics Challenges were effective in meeting the program’s goals.

In addition to appropriate training, teachers reported positive responses regarding their students’ interest and enthusiasm. In particular they reported:

1) That students gained enthusiasm about the world of science and engineering (4.29; SD 0.68), and

2) That the students’ project reports indicated that the program was successful in teaching students more about technology (4.46; SD 0.89), more about problem solving (3.79; SD 1.11), more about math (3.82; SD 1.05), and more about science (3.61; SD 1.25).

Most significantly in the context of the overall mission of the program, when asked whether participation in the program increased, decreased, or resulted in no change in the student’s interest in science or engineering careers, 2 students reported a decrease, 14 indicated no change, and 45 students indicated an increase in interest in pursing science or engineering careers.

ALB conducted her own informal interviews with students, parents, and teachers. She asked four questions: (1) “What do you think about the project?,” (2) “Have you learned any new math skills?,” (3) What do you think about working in teams?,” (4) “Would you like to continue to work with the scientists and engineers?”

The responses from the students were generally positive and the negative responses were largely just expressions of dissatisfaction that the project had to end. The students indicated that they enjoyed working on the robotics, the problems, and especially finding solutions that they could demonstrate and support. Many students suggested that the math was difficult for them, and observed that occasionally they needed to solicit help from their peers, the mentors, or the teachers. These same students also explained that they thought their own math skills increased from applying their mathematical skills in the challenges and by receiving the assistance provided by their peers. Every student indicated that the best part of the day during the project was the team work. They liked the independence of working in learning groups with the scientists, engineers, and teachers as support. Information collected from
parents as well as interviews with students indicated that the project ignited interest in science, math, technology and engineering, and that most students wanted to continue their work in these areas. The plan is to make these informal interviews a permanent part of the evaluation process.

**FUTURE ACTIVITIES AND CHALLENGES**

The enthusiasm of the SET teams and students who participated in the pilot N-STAR VDP might well be one of the essential components of the project’s success. Enthusiasm is evidence of a potential paradigm shift for students, without which the long-term goal of choosing math, science, or engineering as a potential career might not be realized. Likewise, excitement generated among parents and school counselors further enhances the focus on math, science, and engineering as career options.

However, we are totally aware that excitement and enthusiasm are one thing, while enrolling and graduating from science and engineering degree programs is another. Specifically we realize that providing 1) stimulating opportunities to explore, learn, and use math and science principles as these students move through the educational system, 2) information on the selection of advanced mathematics and physics courses, and ultimately 3) information on the choice of a university and the availability of financial aid must be integrated into this program if we are to attain our long-range goals.

As we contemplate the development of such a program and its extension to other Navy Warfare Centers, we are exploring ways to engage both the public and private sectors in providing funding and professional staff to serve as mentors in the program, as well as ways to use existing Navy high school and university internship programs. We recognize that many science and engineering students spend the first part of their programs at community colleges, and we are exploring ways to increase the interest of more community college students in entering four-year engineering and science programs. Finally, as we are all aware, too many talented people, once enrolled, transfer out of science and engineering programs and never obtain their degrees.

There is plenty to be done which goes well beyond the program which we have described here. But we believe (and the evaluations appear to confirm) that we have made an important start at increasing the interest of young people in pursuing careers in science and engineering. We eagerly look forward to the expansion of the program both in terms of its scope and its dissemination to other Navy Centers.

**REFERENCES**


Andrea L. Bengier
Dr. Bengier is the Assistant Superintendent for Instruction and Technology for Stafford County Public Schools. Dr. Bengier has both teaching and administrative experience at all three levels of K-12 education as well as being an adjunct professor for George Mason University and Virginia Commonwealth University. Dr. Bengier prides herself on promoting diversity, especially in the areas of math, science, pre-engineering, and technology.

Eugene F. Brown
Dr. Brown is Professor of Mechanical Engineering at Virginia Tech. He has worked with ONR since 2001 on university-centered Navy 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 and aircraft propulsion.

Ray Gamache
Dr. Gamache is a Senior Physicist at the Naval Surface Warfare Center at Dahlgren, Virginia. His current efforts are focused on the development of Reactive Materials and Protective Armor. A graduate of Rensselaer Polytechnic Institute, Dr. Gamache has worked in the fields of explosives, automated test facilities, and ballistic tracking systems, holding a number of patents and awards in these areas.

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Dr. Hardinge is an educational psychologist who currently works with the Virginia Department of Education's Training and Technical Assistance Centers, at the College of William and Mary, providing professional development programs for teachers. She has worked in public education for twenty-two years and is an adjunct Assistant Professor at William and Mary, teaching courses in collaborative consultation and assessment, as well serving as the college's VDP Project Coordinator.

Robert A. Kavetsky
Mr. Kavetsky is currently on assignment to ONR, where he is the director of the N-STAR program, an initiative focused on revitalizing the S&T base in the Navy’s Warfare Centers. He is a mechanical engineering graduate of Catholic University, and has worked in the fields of hypersonic aerodynamics, explosives, undersea warheads, and mine countermeasures.

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Mr. Kremar is currently the High Speed Ordnance Program Manager at the Naval Surface Warfare Center at Dahlgren, Virginia. He is a mechanical engineering graduate of Tennessee Technological University, and has worked in the fields of penetrator technology, target simulation development and missile survivability analysis.

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Dr. Matkins is an Assistant Professor of Science Education at the College of William and Mary. She was a K-12 teacher for 18 years, and the Virginia recipient of the 1995 Presidential Award for Excellence in Secondary Science Teaching. She has written and published several papers and reports on various issues in teacher education, including assessment, gender and multicultural issues in science education.

Robert L. Stiegler
Mr. Stiegler is currently supporting the USMC Targeting and Engagement Systems and the Office of Naval Research, N-STAR initiative. His recent career experience has included service 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.
APPENDIX

Summer Camp Diary

1) On day one, students experienced the Ball Drop problem. The Ball Drop problem consisted of a robotic vehicle carrying a golf ball that traveled across a bar 7 ft above the ground. A target was placed on the ground at a specified distance from the starting point of the robot. Students were asked to make measurements including robot velocity, ball height from the ground, and distance from the robot to the target. Once each team had completed their measurements they were asked to use a given formula to program in the delay time for the robot to release its ball. Students used carbon paper on top of their target to measure the miss distance of the golf ball to the center of the target. Students were asked to drop their ball within 2 inches of the target center to receive a patch for the Ball Drop problem.

2) On the second day, students learned about electronics where each student was asked to construct their own room alarm system. The alarm system incorporated a magnetic sensor which would turn on when the door is opened. Each student was given a multimeter where they were asked to use their meter to measure the voltage of their battery and resistances across their switches as they were opened and closed. All students within the team were required to construct a working alarm system before a patch was presented to the team.

3) For the third day students were able to shoot a paintball gun and use high-speed video to capture the paintball during flight. Within this problem students were given a high-speed video camera and a high-speed single frame camera. When the students fired the paintball gun a laser beam was able to trigger when the ball exited the gun. The students would use this trigger to turn on the high-speed video and capture the ball during flight. Using a 1 inch grid background combined with the known time between video frames students were able to calculate the velocity of the paintball. Once students calculated the velocity, a wall was placed approximately 2 ft from the gun. Students must use the measured velocity and the distance from the laser to the wall to solve for the delay time of the single frame camera to take a picture of the paintball just before impact. Teams that capture an image of the paintball within 2” of impacting the wall will receive the paintball patch.

4) Students were introduced to the electric gun on the fourth day. Here students worked with two-dimensional kinematics. The electric gun is a solenoid gun that launches a projectile to a distance of up to 6 feet. Students were first asked to determine the initial velocity of the launched projectile. Students used the first of two formulas to calculate the initial velocity through a horizontal launch of the projectile. Once the students have determined the initial velocity of electric gun, the gun is positioned to an angle of 15 degrees. Using a formula provided, students must determine where the projectile will land within 1” of the actual impact to receive their patch.

5) The next two days were dedicated to rocketry. Students on day 5 constructed a rocket as well as learned about the principles of how a rocket works. On day 6 students launched their rockets. Students learned to pack both their chute and engine. In addition, students learned how to measure the height that their rocket reached using trigonometry during flight.

In addition to the robotics and problem scenarios, students were able to participate in different activities. The activities were designed to provide engineering challenges in a more fun and relaxed environment.

6) The first activity each team participated in was the water balloon cannon. The water balloon cannon was capable of launching water balloons over 100 yards. The challenge given to students was to create a firing chart for their water balloon cannon. Each team was given 40 water balloons. Teams would correlate the distance that the water balloon traveled to the launch angle and pull back distance of the water balloon measured for each shot. On the final day students were given a 4 foot target placed at a random position on front of their cannon that they must hit to receive a patch. Using their firing chart, each team was given 3 attempts to hit the target.

7) The second activity students participated in was an egg drop contest. Each team was given a cardboard box, 6 rubber bands, 2 feet of duct tape and two Styrofoam cups. With these materials students constructed a container to hold an egg and prevent the egg from being damaged during drop heights from 20 feet up to 40 feet. Teams whose egg remained intact after the forty foot drop received a patch.
The last activity students participated in was the research project. Students were asked to pick one of the eight Robotics Challenges and create a proposal for developing a new engineering solution improving on present solutions. Students performed research on existing solutions and would then determine a better way to perform the task and present it as a proposal. On the last day of camp, students representing each of the 12 teams presented their proposal to a funding board. The funding board reviewed each proposal and awarded 4 of the 12 teams with a funding patch.

**Rubric for N-STAR project - Individual Evaluation**

This rubric is used to evaluate individual student performance in helping their teams meet all the challenges.

<table>
<thead>
<tr>
<th>Teamwork</th>
<th>1 - SAILOR</th>
<th>2 - MASTER CHIEF</th>
<th>3 - LIEUTENANT</th>
<th>4 - COMMANDER</th>
</tr>
</thead>
</table>
| Individual Team Member | * Chooses not to participate  
* Impedes group from meeting goals  
* Does not complete individual assigned tasks.  
* Discourages sharing  
* Does not participate in group discussions  
* Does not listen to others  
* Not considerate of others’ feelings and ideas | * Participates inconsistently in group  
* Participates sometimes in meeting goals  
* Completes some assigned tasks.  
* Shares ideas occasionally when encouraged  
* Allows sharing by most group members  
* Listens to others sometimes  
* Considers other people’s feelings and ideas sometimes | * Participates in group  
* Participates in meeting goals  
* Completes most assigned tasks.  
* Shares ideas readily.  
* Allows sharing by all group members  
* Listens to others consistently  
* Considers other people’s feelings and ideas | * Participates actively  
* Helps direct group in meeting goals  
* Thoroughly completes assigned tasks.  
* Shares many ideas related to the goals  
* Encourages all group members to share their ideas  
* Listens attentively to others  
* Empathetic to other people’s feelings and ideas |
| Individual Team Member’s Contribution to Problem-solving and Cohesion | * Chooses not to participate in problem-solving  
* Promotes fragmentation of group | * Offers suggestions occasionally to solve problems  
* Demonstrates effort sometimes to help the group work together  
* Does not impede group’s efforts | * Offers suggestions to solve problems  
* Demonstrates effort to help the group work together  
* Encourages the group in persisting in efforts to solve the problems. | * Involves the whole group in problem-solving  
* Actively participates in helping the group work together better |

* N-STAR Instructional team (Matkins, Hardinge, Inge, Matheson, Mason, Southall, 2005. From, Hilary McLeod, Peel DSB. Adapted from "The Education Technology Journal", Jamie McKenzie, Vol. 7, No 2, October 1997*
Problem #1 Ball Drop (From 2005 Summer Camp Programming Manual)

In the ball drop problem each team will be given a Mindstorms robot that was constructed to traverse across a steel pipe at a height of ~ 2.3 meters. The robot is designed to travel at a fixed velocity across the pipe. At a specific point the robot will open its claws to release a ball. The time that the ball is released is determined by a time-delay that each team must input.

Your mission will be to determine the time to release the ball in order to hit a target.

To determine the delay time at which the robot must release the ball, students must obtain three measurements. The first is the height of the ball above the ground “H”. Second is the distance from the initial position of the ball to the point at the center of the target. The third measurement is the velocity. The velocity is measured by measuring the time it takes to travel a measured distance. For example if the robot travels 1 meter in 5 seconds then the velocity is \( \frac{1 \text{ meter}}{5 \text{ seconds}} = 0.2 \text{ meters/second}. \)