Anne Arundel County Public School’s
ROV Summer Bridge Camp
July 28 to August 8, 2008
South River High School

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Background

The U.S. is now coming to grips with the scope of the problem that shortages of qualified scientists and engineers are imminent if action is not taken to stimulate, and retain, homegrown S&E talent. A report by the National Science Board (NSB) states that the future strength of the US [science and engineering] workforce is imperiled and calls for more federal funds to support US science students and to improve science teaching. According to the report, entitled ‘The S&E Workforce: Realizing America’s Potential’ the number of S&E jobs filled by foreign-born PhDs in the States grew from 24% in 1990 to 38% in 2000. The report noted that the United States may not be able to rely on the international S&E labor market to fill unmet skill needs.

The NSB wants the Federal Government and its agencies to pull out all the stops in mobilizing stakeholders to increase the number of US citizens pursuing science and engineering studies and careers. It offers several specific recommendations to achieve this, including more funding and incentives for undergraduates, expanded programs to draw minorities and women to the field, more competitive benefits for S&E graduates.

The Anne Arundel County, Maryland Public Schools are actively pursuing this challenge. County School Superintendent Dr. Kevin Maxwell has opened one STEM (Science, Technology, Engineering and Mathematics) Magnet High School Program in 2008 and will open a second in 2009 plus STEM programs in the STEM Feeder Middle Schools in 2010. The elementary schools will also support the STEM initiative.

The County’s STEM web site notes that students at the STEM Magnet High School will learn and work in a challenging, high-tech atmosphere where collaboration is expected and questioning and critical thinking routine. The web site also states imagine a school where students work to solve local and global interdisciplinary community-based problems hand in hand with their peers, teachers, mentors, community partners and STEM professionals in residence within the school setting. STEM Magnet High School students will experience an environment steeped in integrated project-based learning, take advanced STEM coursework, avail themselves of non-STEM classes from the host school’s rich array of course offerings and engage in STEM job shadow experiences and research internships throughout their four-year high school experience. Upon graduation, students will have
- 21st century high-tech communication, presentation and workplace skills,
- Project management and team leadership expertise,
- STEM research and publication experience,
- Foundational advanced or AP coursework in all disciplines,
- International awareness and perspectives,
- Global social consciousness,
- Commitment to lifelong learning

STEM Magnet High School students will be highly sought after by select colleges and industries, regionally and nationally.

As the County’s STEM Program evolves, one of the initiatives has been to have those students who are eligible to apply to the STEM Magnet School, to participate in a 2-week Summer Bridge Camp. A recent Maryland Gazette article entitled Bridge to the Future quoted Dr. Maureen McMahon who heads the program, "We are engaging these new ninth-graders in many high tech experiences and STEM rich experiences that few high school students would receive until college," "What we are trying to do in these summer bridges is link education with application. It really answers the question 'So what?'" said Dr. McMahon. "We are saying here it is, it's exciting and it can be your career."

South River High School conducted a 2-week ROV Summer Bridge Camp from July 28 to August 8, 2008 which was a merging of two efforts; the Anne Arundel County Public Schools STEM Program and the Navy’s National Naval Responsibility for Naval Engineering Program, to encourage students to pursue rewarding careers in science and engineering in general, and naval architecture, marine engineering, naval engineering, and advanced marine design. The NNRNE is administered by the Navy’s Office of Naval Research.

The original idea for the ROV Summer Bridge Camp came from Ms. Katrina Gillmeister. Ms. Karen Fowler transferred the idea into a working roadmap and secured the funding and facilities for the ROV Summer Bridge Camp at South River High School. The camp was taught and facilitated by Ms. Sara Veinbergs and Mr. Robert Wilson with assistance from Dr. Doug Levin of NOAA and Mr. Mark Hammond of SERC.

**Purpose**

The overarching purpose of the summer bridge camp was to give near-future STEM student participants a feel for the real world of science, technology, engineering and mathematics. The technical purpose of this specific program was to introduce the students to real world environmental problems affecting the Chesapeake Bay and to have them design, build and test a remotely operated underwater vehicle in a tributary of the Chesapeake Bay to enable them to collect water samples of various types (of their selection) to analyze and to draw conclusions from. It also serves as an experiment with different teaching approaches both in the STEM schools, relative to Summer Bridge Camps which give near-future STEM students an experience in STEM and another teaching method relative to the Navy’s Sea Perch program. This effort was to be a very, hands-on experience, both technical and relative to working with teams and was planned to involve the Anne Arundel County Public Schools, the Smithsonian Environmental Research Center (SERC), the Navy and NOAA.
The purpose of this report is to document the summer camp with emphasis on lessons learned, both good and bad, relative to the curriculum which we created. It also hopes to address: how we taught the students about rovs and the aspects of naval architecture which they needed in order to design their rovs; how well the rovs operated; the innovative techniques and components which the students created to collect their data; the type of scientific assistance that they needed in order to achieve a solid understanding to the environmental problem which they selected; and types of instruction needed to analyze the data which they took. Interpersonal aspects relative to the instructors and the students also needs to be addressed which would benefit future endeavors such as this. This effort was undertaken with an emphasis on augmenting the Sea Perch program to include much more engineering and scientific problem solving instead of just a hands-on program to build and operate a rov.

Preparation

Since the South River High School ROV Summer Bridge Camp was the first of its type created for the STEM program, a process was started as a top level plan but there was only minimal planning done at the curriculum level, mainly relative to teaching concepts such as buoyancy, relationships between weight, buoyancy and vertical and longitudinal centers of gravity and moments centers. The training given to the students relative to measuring and cutting pvc pipe and connecting and hooking up electrical wiring and switches was minimal and mainly taught as on the job training.

The remotely operated underwater vehicle concept chosen to be built was a combination of three teaching efforts. One was the Sea Perch ROV program that was modeled after the freshman introductory program run by the Center for Ocean Engineering (Discover Ocean Engineering) at the Massachusetts Institute of Technology. Under MIT’s Sea Grant Program, the Sea Perch program was developed for ONR in 2002. This effort was performed under the Navy’s NNRNE Program (www.seaperch.mit.edu). MIT Sea Grant put on their first workshops to teach school teachers and mentors in 2003 and they continue to manage this effort for ONR. The Society of Naval Architects and Marine Engineers (SNAME) also have a program which is funded by ONR in collaboration with MIT (www.SEAPerch.org); these programs are separate but work together. The purpose of these Sea Perch efforts is to teach students how to work as a team to build a propulsion system, develop a controller, investigate weight and buoyancy and investigate other naval engineering principles. This ROV Summer Bridge Program also used Dr. Doug Levin’s ROV in a Bucket program. Dr. Levin uses his ROV in a Bucket program to educate school age students about environmental issues for NOAA (ftp://noaa.chesapeakebay.net and doug.levin@noaa.gov). The ROV Summer Bridge Program takes all of these processes a significant step forward, where the rov is a tool to be used by the students to solve a real world problem when combined with proper instrumentation and analysis techniques to study the river water and the environment.

Material found on the web for these three efforts was used extensively during the conduct of the South River High School ROV Summer Bridge Camp. General background information on this type of rov as a teaching tool can be found in the book Build Your

Instructors

The ROV Summer Bridge Camp at South River High School in Edgewater, Anne Arundel County, Maryland, was created by Ms. Karen Fowler, Advanced Studies and Programs Resource Teacher... The instructors were Ms. Sara Veinbergs, a Chemistry teacher at South River HS who usually works with AP level students and will work with STEM students in the future and Mr. Robert Wilson, a retired naval and marine systems engineer who is knowledgeable in the field of rovs, naval architecture and marine vehicle design. Dr. Doug Levin from NOAA and Mr. Mark Hammond from SERC were also involved to share their experiences with rovs and environmental science issues respectively.

Participant Selection

During the South River High School ROV Summer Bridge Camp, notices were sent out to over 200 students who would be going into the 8th and 9th grades and who showed academic strength in the science, technology, engineering and mathematics areas of study. The students targeted were students who feed into South River’s STEM Magnet school who were in Southern Middle, Central Middle, Annapolis Middle and Bates Middle. Eighteen students applied but only 13 participated in the summer bridge camp. It must be noted that the notices relative to the summer bridge camp came out rather late and many who might have applied were already committed to other activities or vacation.

Equipment

Mr. Wilson and teachers from about 9 elementary and 1 middle schools in Anne Arundel County previously had experience with the Sea Perch ROV which is used in the Navy program. Sea Fox is a larger derivative of Sea Perch that is discussed in the book Build Your Own Underwater Robot and Other Wet Projects by Harry Bohm and Vickie Jensen, published by Westcoast Words in 1997. During the course of putting the rov summer camp together, we learned from SERC about the ROV in a Bucket concept that is used by Dr. Doug Levin in his NOAA undersea education program. The main difference between the two concepts pertains to the motors and controllers; the Sea Perch uses small motors that are placed in film type canisters and sealed with wax and the ROV in a Bucket uses larger bilge pump motors like those suggested by Bohm and Jensen in their Sea Fox version. Also relative to the controller wiring, the Sea Perch wiring is soldered to the motors and to the switches in the controllers while the ROV in a Bucket uses crimped connectors on the wires which slide on to the spade connectors on the switches. The electrical connections on the bilge pump motors are permanently wired but need to be spliced onto the 30 feet of speaker wire used to connect the controller switches to the motors.
In preparing for the rov summer camp, parts from the ROV in a Bucket parts list were purchased and paid for by the Office of Naval Research but none of the pipe was precut or predrilled as is in the ROV in a Bucket kit; this permitted the students to design any shape or size rov that they wanted to enable them to have an rov that would function satisfactorily when they wanted to collect environmental data for analysis.

- A small vise to hold small switches when soldering if soldering is required. A Wilton Model 63500 2 ¾Ø Vacuum Base vise sold for about $30 worked well.
- Battery chargers that will recharge a battery in about 2 hours and shut off at the appropriate voltage are needed.

Day-by-day Program

- Day 1—Learn about rovs and buoyancy (videos, demos, calculations, experiments). A video taken in California relative to operating a Sea Perch-like rov was shown as an introduction to the concept. A brief lecture on weight and buoyancy relationships was given and buoyancy calculations and experiments in the classroom were conducted. The students then started to work on their rov designs.
Day 2—Learn about the ecology of the Chesapeake Bay from lectures by SERC and see NOAA’s scientific rovs in action while on a NOAA research vessel. The second day was spent entirely at SERC. They were first introduced to the Chesapeake Bay Estuary and its environment. They then went aboard the NOAA craft to learn about side scan sonars and bottom sonars and the instrumentation used aboard the NOAA boat when conducting environmental experiments. They then went out into the Rhode River and assisted in conducting the experiments and watching the sonar returns on screens. After the NOAA vessel came back to shore, the students returned to the classroom in SERC for more detailed instruction on environmental data and how to take data samples and how to analyze the data.

Day 3—Each team decided on the environmental issue that wanted to tackle and began to design their rov. Then they started construction. Using the information gained from Day 2’s lectures and experiences and after searching the web, each team selected a real world problem that they wanted to address. Each team then gave a brief presentation to the group relative to what they planned on addressing and how. Then the design work began on paper and after a brief review by the instructors, each team began the construction phase.
Day 4 Complete construction of their rovs and check them out electrically. Fix structural and electric/controller problems and design their environmental experimental equipment and camera holding apparatus. Day 4 was a very busy day. The students needed to learn to make accurate measurements and to use the tools provided. Figuring out how to hold and secure the video camera on each team’s rov was a challenging effort. And performing the wiring was difficult. In retrospect, they needed better instruction and practice relative to stripping wires and crimping the crimp lugs onto the wire. And the switches were so small, even setting the control box down on the table hard often caused all of the wires to become disconnected. The wiring became a very frustrating aspect of the summer camp experience.
Day 56 Test their rovs in a swimming pool. Fix buoyancy, weight and longitudinal center of gravity position problems. The class then moved to the Special Education Building where there is a swimming pool. But the pool had been drained and then partially refilled with water which did not have chlorine and other chemicals in it, so the students could not go in the water and since the water was low, this caused some problems. The biggest issue was that the students had to work on finding the right relationship between buoyancy and weight and the rov’s center of gravity location so that it would float level and in a slightly positive buoyant position. Also, the tether was negatively buoyant so they had to compensate for this. It was a challenging day.
Day 6 - Competition day in the swimming pool. Various obstacles were set up for timed runs and demonstrating the ability to maneuver and push or carry a floating object and return it to the starting point; also timed. They still had several electrical and structural problems to work on. What was hoped to be a competition between the various team’s rovs, ended up being mostly a day to keep working on and fixing buoyancy, center of gravity and electrical problems. There was a lot of frustration but there was also a lot of learning relative to figuring out the right problem to work on and fixing it. This is what engineers face daily. Two teams were able to operate their rovs in the competition. The competition involved timed trials and maneuvering around floating objects and pushing or carrying larger pieces of Styrofoam from one location to another.

Day 7 - At SERC to operate their rovs from the floating dock and take data. All teams still had electrical, structural and instrumentation issues to solve. The teams then went back to SERC to work on their rovs in the Rhode River. Again, they fought numerous operational problems and had to keep working on the instrumentation which they designed and fabricated to take their environmental data. Some teams actually were able to take some data samples on this day.
-Day 8: Continue to work on the ability to collect environmental data. Start to analyze the data with the assistance of SERC scientists who provided guidance and sample analysis equipment in the education room/laboratory. Start to prepare each team’s power point presentation. One team spent the entire day rewiring their rov twice without taking any data. One team collected data quite successfully and began to analyze it with the tutelage of a scientist from SERC. The others were somewhere in between. Some members of each team also started to create their team’s Power Point presentation.
By Day 9, every team was able to operate their ROV (to varying degrees) and all took some form of environmental data to be analyzed; again to varying degrees. They then completed their first attempt at their Power Point presentations and gave them as a dry run to their peers and instructors. Much work was still needed but they did it.
-Day 10 each team gave their power point presentation to peers, family and friends and academicians. Then demonstrate how they took data with their rovs from the floating docks in the Rhode River. End with a picnic at SERC. The first hour was hectic, making last minute corrections to their presentations. The audience was smaller than expected but represented a good cross-section. There were about 10 teachers from Texas who were visiting SERC and attended the first couple of presentations. One teacher then came back to take many photos of the work that the students had done. There were several parents, grandparents and friends. And there were representatives from SERC and Anne Arundel County Schools. A small group from the Navy were scheduled to come but did not. The bottom line is that the students did a very good job with their presentations. They then took the attendees down to the dock to see them run their rovs in the Rhode River and take data. Finally, we had a picnic and formally ended the excellent 2-week summer bridge program.
Environmental Issues Selected

The students heard a lecture by Mr. Hammond, Director of Education at SERC relative to environmental issues which affect the world and especially, the Chesapeake Bay. Each
team then used SERC’s web site plus others to establish the question or hypothesis which they wanted to address with their rov. The following five were selected:

- How do the levels of hypoxia in different places of the Chesapeake Bay affect the blue crab-Baltic clam predator-prey relationship?
- PH and how it kills
- How does depth affect population density of barnacles?
- How is water clarity affected by erosion in different places?
- How does temperature vary with water depth?

**ROV Designs**

The design process for each of the five teams was to determine what information that they needed to provide some insight into the problem that they selected and what type of instrumentation did they need to provide this information. This then became the driver in the design of their rov. Each group really had a different design idea and went about designing their rov and their data collectors in drastically different ways. This aspect shows the importance of having raw materials for them to work with and not pre-cut or prepared structural members for their rovs. It needs to be emphasized that each team showed real creativity relative to the techniques and sample collectors which they developed for the data that they needed for analysis...

**Team 1’s Design and Rationale**

- Designed as a box with a creative set of arms forward to hold a camera
- Very creative method to collect water samples at various depths using a plastic cup, a lid and rubber bands which would not permit any water in the cup until the top was moved with the rubber bands. It was quite successful.

**Team 2’s Design and Rationale**

- Designed as a box with a creative structural means of holding the camera.
- Water depth was determined via marks on the tether
- It worked well in the pool but the motors and props were not powerful enough to hold it in position in the current near the dock’s pilings, so they added a 5-foot long pvc pipe to it which was hand held at the depths which they needed.
- Having enough light for the TV camera was an issue. A 5-bulb light was added and it provided enough light to be able to record the pictures and count the barnacles on the pilings.

**Team 3’s Design and Rationale**

- This team started with a box type structure but wanted to be creative so they added a relatively long tail which was structurally strong and supported two motors and props on a horizontal type stabilizer.
- The longitudinal center of gravity was so far aft that it wanted to float vertical
- When they added weight forward to balance the rov longitudinally, the weight increased significantly and there was not enough buoyancy, so it sunk tail first.
They also wanted to collect water samples, so they added a plastic bottle forward but when the top was on the bottle, it added more bow-up buoyancy, making the longitudinal center of gravity/center of buoyancy relationship so far off, that they had to take data by letting the rov sink to the desired depth, holding it by its tether.

They did take temperature data by tying a thermometer to the forward end of the rov.

**Team 4’s Design and Rationale**

- This team designed their rov as a relatively big cube to enable it to put a large water sampling unit in the middle. That did not work but they left the size large.
- They created a cup holder on their rov which worked but it initially was on one side, causing a lateral balance problem.
- They were able to take samples in the river at SERC a couple of times but on the third try, the rov came apart, destroying their improvised instrumentation. But they had taken enough data to enable them to analyze it properly.

**Team 5’s Design and Rationale**

- This team used a cube shaped rov with a very creative bottle method of creating water samples.
- This team had the worst luck at keeping the wires on the spades in the control box; they must have rewired the rov 5-6 times. They also helped out other teams with similar problems.
- Their bottle had a slit on the bottom. The rov was lowered down into the water with the slit down and when it got to the proper depth, using some string, they rotated the bottle so that the slit was now up and the bottle filled with water. They were then able to dump the water into test tubes for analysis
- Their rov had very good balance and maneuverability characteristics.

**Peer Review**

The Peer Review process worked quite well, even though the audience was not as large as hoped for. After the instructors commented on their dry run relative to too much animation and backgrounds and lettering that blended, they did a super job of fixing the problems and of remembering the tips which the instructors gave them relative to certain points of their presentations.

**Issues**

**Successes to Build Upon**

- When the rovs worked, they were able to make rapid progress at collecting data.
- Having a knowledgeable science teacher as part of the team who is good at teaching and controlling a class and is good at scientific procedures, is a must.
- Teamwork skills are such a key part of making the summer bridge camp work as a smooth operation.
- Students are good at different things or abilities and you must let these talents fall out as the process progresses.
- The students benefit greatly from real world experiences, such as seeing professional quality rovs function while on the NOAA research vessel and seeing and working with the tools used by the environmental scientists at SERC.
- Designing their own rov to do the mission which they chose was a very positive experience. This also applies to fixing their own problems due to overlooking some of the aspects of rov or naval architectural design rules or processes.
- Once the rov was working and kept working, they were able to work on more environmental or other problems than they had selected.
- Having a clear pool of water (like the swimming pool) was a necessity to solving rov operational problems. Trying to accomplish this same thing in the unclear water in the Rhode River at SERC was useless.

**Items That Need Fixing**
- The motors were strong enough to permit the rovs to function quite well in the swimming pool but not strong enough to handle the current near pilings in the river.
- The ROV in a Bucket approach to wiring was selected prior to the camp because it eliminated soldering the wires to the switches. But the connectors kept coming off of the spade posts on the switches and the students lost an inordinate amount of time constantly fixing them. Finally, we reverted back to soldering the wires to the switches which solved the problem.
- A couple of the students were taught how to solder but they never got skilled at it and some of their soldered wiring came apart, requiring new switches to be put in the controller and again soldered by an adult.
- If the wiring had functioned satisfactorily at the start, the students would have needed more guidance by SERC scientists. Future plans must consider a larger science set in the curriculum.
- Battery life is an issue. The batteries that we were using need to be recharged each night when they are being used and at least once a month when not in use. The batteries should only be charged up to a certain voltage and never discharged below a certain voltage. There were no directions available to tell us that. The inexpensive type of charger that we had also would not shut off at the proper voltage; it kept charging and got very hot.
- Once the students have built a rov, they need to determine its weight so that they can then determine what length the ballast tubes should be cut. You can always add some ballast weights to the rov but resizing the ballast tubes is tougher.
- You need a good selection of ballast weights. Usually 0.5, 1.0 and 2.0 oz lead fishing weights are adequate.
A Self-Assessment by the Instructors

-The students needed to be taught about rovs and the aspects of naval architecture which they needed in order to design their rovs. How did we do? The pre-summer camp effort was not thorough enough relative to this area. Better detailed curriculum development is needed with handouts, presentations on dimensional analyses were needed and problems which each team needs to work and experiments relative to buoyancy, weight and center of gravity with appropriate equipment need to be available. During the first day, this material was in the Instructor’s heads and the ideas got across, but not thorough enough.

-One metric relative to the success of our teaching effort was how well the rovs operated. How did we do? The rovs functioned from a mechanical viewpoint, but they were not near optimum designs relative to weight, buoyancy and center of gravity location, especially when considering the sample collecting devices. Again, teaching the fundamentals of naval architecture relative to buoyancy, weight, center of gravity and righting-moments is necessary very early in the program.

-Innovative techniques and components were needed to be created for the students to collect their data. How did we do? Here, most of the teams excelled. And it demonstrated their own creativity. Some solutions only lasted for two or three attempts to collect data, but their approaches were very innovative.

-A level of scientific assistance was needed in order for the students to achieve a solid understanding to the environmental problem which they selected. How did we do? More preparation is needed here. We counted on the scientists from SERC to assist us here, but not enough coordination was done between the Instructors of the Summer Camp and the SERC Scientists to understand what each was expecting. The fact is, neither of the two groups knew what to expect since this was the first time to attempt such a summer camp.

-A level of instruction is needed for the students to analyze the data which they took. How did we do? Again, neither of the two groups knew what to expect since this was the first time to attempt such a summer camp.

-Interpersonal aspects are needed between the instructors and the students and between each of the members of the class and of each team. How did we do? When selecting people, whether students or adults to work in teams, an individual’s personality comes into the equation relative to being able to work in a team setting. We had students who did not fit into the fast paced setting of the summer camp and who became a disruption to the majority of the summer camp participants. Can this be rectified in the future? Hopefully. Or should smart but disruptive students be removed from the summer camp? This needs to be considered.

-This effort was undertaken with an emphasis on augmenting the Sea Perch program to include much more engineering and scientific problem solving instead of just a hands-on program to build and operate a rov. How did we do? This was a resounding YES. We believe that it was an incredible experience for both the students and the Instructors. But
comparing our approach relative to the rov and that used in Sea Perch, more discussion is useful. We used the pvc pipe corners which came from the ROV in a Bucket parts list because corners were well defined; Sea Perch does not use corner joints that permit attaching 3 pipes per corner at right angles to each other. The ROV in a Bucket kits come with all of the sections of pvc pipe cut to length and the brackets for the motors drilled and ready for attachment. Sea Perch provides pipes in about 12 inch long lengths while in the ROV Summer Bridge Camp, we provided the pipe in 5 foot long sections to enable the students to make their own decision relative to rov size. The motors and propellers used in the ROV in a Bucket and in the Summer Camp were larger and more powerful than those in Sea Perch and the motors were already sealed and were wired, which was easier to work with and did not involve the mess associated with potting the wires in wax. The Instructors believed that using crimped electrical connections would be much easier to connect and would allow wiring changes if necessary and more rugged, but the students continued to have the wiring come apart until we finally soldered the wires to the switches. The larger motors and propellers worked well in the swimming pool but apparently still did not produce enough thrust to permit necessary maneuvering in the current around pilings at SERC on the Rhode River.

Recommendations for Implementation in the STEM Program

- Explicit lessons on a variety of topics like you listed
- Lessons on pH, salinity levels, local marine life, etc. to be done with individual groups as needed for them to understand the data or to make conclusions based on their data
- Switches soldered and pre-assembled so the focus of the bridge remains on purposeful design and construction to complete a task/collect data
- Marine scientists/researchers accessible during data collecting days to help with testing and analysis
- A panel discussion with scientists/researchers from a variety of organizations to see the final products