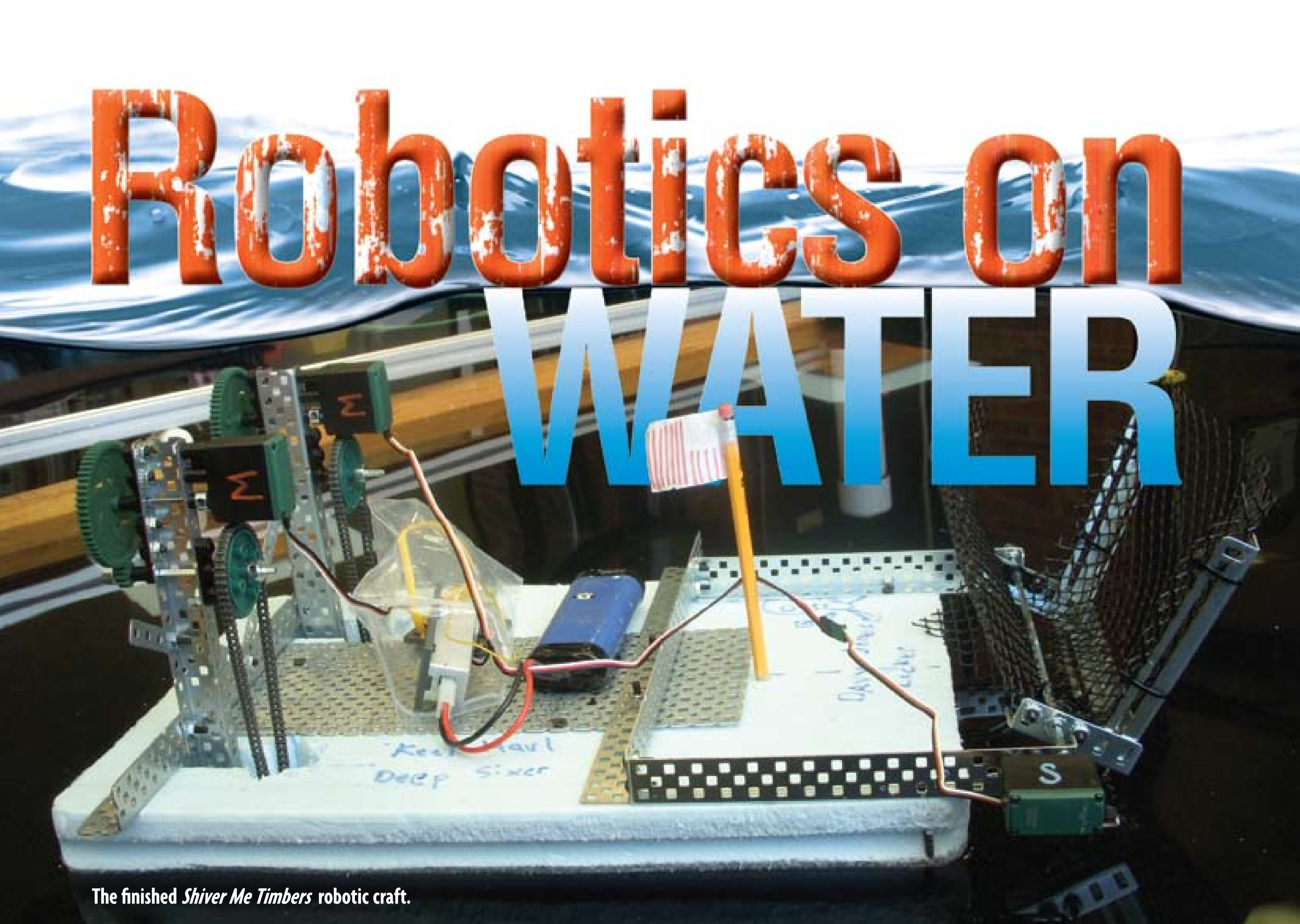
Robotics on WATER



The finished *Shiver Me Timbers* robotic craft.

A project-based learning activity focused on U.S. Coast Guard missions

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Research has demonstrated that project-based learning (PBL) is a highly successful instructional tool, and is particularly useful when teaching science, technology, engineering, and math (STEM; Barron et al. 1998; Marx et al. 1997; Gordon 1998; Blumenfeld et al. 1991). "Engineering Challenge for the 21st Century," a weeklong teacher workshop sponsored by the National Science Foundation, uses PBL to help students and teachers build STEM skills.

The workshop, hosted by the U.S. Coast Guard Academy in New London, Connecticut, features the Coast Guard Academy Robotics on Water (CGAROW) project. The goal of CGAROW is to stimulate teamwork, foster creativity, encourage strategic planning, and develop practical scientific and engineering aptitude while building robotic crafts.

In addition to participating in PBL activities such as CGAROW, teachers also learn technical writing tips and teamwork strategies that can be used to make PBL activities more effective for students. This article describes the teacher workshop, the CGAROW project, and its application to the classroom.

About CGAROW

In 2004, the Coast Guard Academy developed CGAROW to encourage high school juniors to pursue STEM careers and learn about Coast Guard missions. High school students typically complete this activity over the course of four days (13 hours). Teachers participating in the Engineering Challenge for the 21st Century workshop, however, complete an abbreviated version of CGAROW that can be fit into a single school day.

Each team of four teachers is given competition rules (Figure 1, p. 50), guidelines and hints, a kit of materials, and seven hours to complete the CGAROW project. The goal is to design and build a radio-controlled floating robotic craft that will complete Coast Guard missions—such as containing oil spills, conducting rescue operations at sea, or stopping the transport of illegal drugs—within a 3 × 3 m (10 × 10 ft.) water-filled arena.

What is PBL?

Project-based learning, or PBL, is a curricular model driven by carefully selected projects. PBL exemplifies the core values of the scientific process, including peer discussion and collaboration, problem-solving skills, modeling, testing, data analysis, and forming conclusions. PBL projects have two primary characteristics:

1. Projects are derived from real-world problems, often involving discussions leading to practical solutions.
2. Projects are student-centered and hands-on, requiring students to take ownership of the problem with minimal assistance from the instructor and collectively design an investigative approach to address the problem and formulate a viable, concrete solution.

Teams earn points for their crafts' successful completion of various tasks during a four-minute competition period. (A description of the point assignment per task is given in Figure 2.) Prior to design, teams decide which tasks to accomplish, and then design and build their robotic crafts with those tasks in mind. The orientation of each task within the arena is shown in the photo below, and example crafts created during the 2009 teacher workshop are shown on pages 49 and 51.

Results

Although the kit of materials and the instructions given to each team in the teacher workshop are the same, the final products are remarkably different. One such product, the *Shiver Me Timbers* watercraft (p. 49), used a "bulldozer" function to collect, transport, and deploy Ping-Pong balls, which represent an oil spill. Using the materials in the kit, the team constructed an L-shaped carriage from the

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Illustration of the water-filled arena and orientation of all mission tasks.

FIGURE 1

Competition rules.

1. Use only materials from your kit to construct your craft.
2. At end of competition, disassemble your craft and return the materials to their proper bags.
3. Do not cut, bend, or mutilate any part of your kit, except for the following: foam board, plastic mesh, rubber bands, strings and tie wraps, and single-hole metal strips.
4. The finished craft must be no larger than 46 × 46 × 46 cm (18 × 18 × 18 in.).
5. Do not test the craft in water without prior approval of a cadet or faculty advisor.
6. Use provided towels to dry your craft every time you pull it out of the water.
7. Crew swap:
   - During speed test, a second driver must take control at midpoint turn.
   - During competition round, a second driver must take control after two minutes.
8. Competition rounds last four minutes.
9. Each team gets one speed test (maximum 60 seconds) and two 4-minute competition rounds. Your team must be ready to go when called.
10. Handling craft after a round has started results in 100-point penalty per instance of handling.

metal plates provided and covered it with plastic mesh. This prevented the collected balls from moving along the surface of the boat or falling through the extension gap between the carriage and the mounting plates. Servo motors—electrical devices with an output shaft used for precise rotational movements—controlled the carriage, and two additional stepper motors propelled the robotic vessel through the water.

CGAROW in the classroom

Workshop participants complete postcompetition assessments on the construction of the robot (in the form of a technical report) and on team dynamics (in the form of a survey). (**Editor's note:** For information on the technical writing and teambuilding aspects of the workshop, see Figure 3, p. 52.)

When the CGAROW project is implemented in the classroom, a variety of assessment tools can be used to measure its effectiveness. For example, students can record a detailed log or journal and document all investigative efforts in the design, construction, testing, and operation of the vessel. They can also write research reports—either individually or as a group—on the working principles of

FIGURE 2

Point assignments per task.

Coast Guard mission areas	Tasks	Points per task	Total points possible
Get underway	Weigh anchor	50	50
Search and rescue	Rescue survivors (seven total) by placing on vessel	70	490
	Deliver survivors to hospital	130	910
Marine environmental response	Collect oil spill (40 Ping-Pong balls)	10	400
	Deliver spill to processing	20	800
	Spill is not contained (floating outside rope)	–1	–40
	Bonus for containing (inside the rope) half or more of the oil in processing	200	200
Aids to navigation	Set red or green buoy (anchor in watch ring)	100	100
	Set both buoys (anchors in watch rings)	300	300
	Energize lighthouse	100	100
Maritime law enforcement	Stop drug runner (knock off rail in water)	150	150
	Catch drug runner (on vessel)	250	250
	Put drug runner in jail	500	500
Flight operations	Land helicopter on vessel	200	200
	Helicopter falls in water	–100	–100

boats, simple machines and gears, buoyancy and flotation, and radio-controlled operation of vehicles. Or, the teacher can evaluate each group vessel's performance during the competition through its collection of points.

As is the case in many other STEM projects designed for an entire class, there is a cost associated with purchasing the CGAROW materials. Teachers can buy a materials kit through VEX Robotics for about $850. There are many funding opportunities available for teachers interested in this project; teachers can apply for local, state, and national grants built on STEM initiatives. Other funding sources may be available through local universities with active engineering departments, or businesses within the technology or telecommunications sector. Teachers can also inquire about possible equipment donations or competition sponsorships between neighboring schools.

Conclusion

The CGAROW experience provides students with an opportunity to model the typical activities and tasks undertaken by the Coast Guard to secure the sea boundaries of the United States and abroad. Working in groups, students learn about the wide array of tasks their vessels must accomplish, and they, in turn, must work together to develop a vessel that can float, move expeditiously, and navigate obstacles to accomplish the array of tasks. Students also learn about the scientific process, engineering principles, the working principles of boats, buoyancy and flotation, simple machines and gears, and radio-controlled operation of vehicles. Teachers who want to take part in this project can contact the authors of this article for more information. ■

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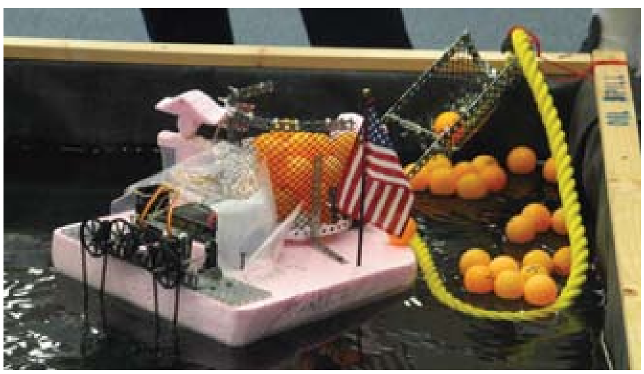

Robotic craft picking up the Ping-Pong ball "oil spill."

Acknowledgments

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References

Barron, B.J.S., D.L. Schwartz, N.J. Vye, A. Moore, A. Petrosino, L. Zech, J.D. Bransford, and the Cognition and Technology Group at Vanderbilt. 1998. Doing with understanding: Lessons from research on problem- and project-based learning. *The Journal of the Learning Sciences* 7: 271–311.

Birch III, J., K. Wosczyna-Birch, R. Adrezin, A. Angle, B. Richards, and P. Jaramillo. 2008. Integrating professional skills in the 21st century engineering and technical curriculum. Paper presented at the American Society of Mechanical Engineers International Mechanical Engineering Conference and Exposition, Washington DC.

Addressing the Standards.

The following National Science Education Standards (NRC 1996) are addressed in this activity:

- Science as Inquiry (p. 173)
- Physical Science (p. 176)
- Science and Technology (p. 190)
- Science in Personal and Social Perspectives (p. 193)

Blumenfeld, P., E. Soloway, R. Marx, J. Krajcik, M. Guzdial, and A. Palincsar. 1991. Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist* 26 (3–4): 369–398.

Gordon, R. 1998. Balancing real-world problems with real-world results. *Phi Delta Kappan* 78: 390–393.

Marx, R.W., P.C. Blumenfeld, J.S. Krajcik, and E. Soloway. 1998. Enacting project-based science: Challenges for practice and policy. *Elementary School Journal* 97: 341–358.

FIGURE 3

Technical writing and teamwork.

In addition to completing the Coast Guard Academy Robotics on Water (CGAROW) project, science teachers participating in the workshop learn technical writing skills and teamwork techniques to foster better writing and group work in their classrooms. The participants use their newly learned team-building strategies on a variety of STEM activities, including the CGAROW project.

Teamwork

Using the DISC Behavioral Model to integrate teamwork into a project-based learning environment significantly improves both individual and student team performance (Birch et al. 2008). DISC is used as a psychological inventory to assign students to teams and ensure balance of the various behavioral types. Students complete a survey that characterizes them as one of four types. The acronym, DISC, is described below:

D	**Dominance**	How one responds to problems and challenges
I	**Influence**	How one influences others to his or her point of view
S	**Steadiness**	How one responds to the pace of the environment
C	**Compliance**	How one responds to rules and procedures set by others

In the teacher workshop, project teams consist of four participants and are assigned by the instructor based on DISC profiles. Every attempt is made to have one member from each key behavior style, as each brings a unique set of talents to maximize the team's effectiveness. The instructor plays an important role in the team's effectiveness by watching the interactions and making observations and recommendations that facilitate cooperation and teamwork. For instance, if one team member monopolizes the project, the instructor can emphasize the importance of teamwork and equal participation to ensure a positive, productive experience.

Technical writing

The success of a science project is dependent not only on the ability of the group to work together and accomplish the predefined tasks, but also in communicating the methods used when accomplishing these tasks. The ability to describe science in a sound, clear, and cogent manner is a critical part of the scientific process. Thus, technical writing is a major component of the CGAROW project.

During one teacher workshop, an English professor with expertise in technical writing explained the major points in drafting a technical report and assigned teachers the task of writing a technical report on the CGAROW project as a group. The major points included creating outlines and using correct grammar, punctuation, and clear and concise language. In the classroom, science teachers can collaborate with language arts teachers to help students develop their writing skills.