# "ROBOT CHALLENGE" MAKES STUDENTS THINK LIKE ENGINEERS

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**<u>Abstract:</u> This project involves taking a "usual" science project and extrapolating it to become a finished engineered product, with all the requirements and details that this entails. The product selected for the experiment is an inexpensive artistic walking robot, which students build from scratch as they learn to cope with the challenges of a competitive marketplace. Boys and particularly girls learn and have fun preparing for these activities, and earn points for performance, workmanship, creativity, report-writing and oral presentations, all skills an engineer (and many other professionals) must develop to be successful in today's job market. Options are available to meet the STEM needs of both technical and non-technical students.**

It has been said that "Education is not about filling a bucket but lighting a fire." Our STEM mission is to light a fire for students to become eager to think like engineers by experiencing the wonder of creating their own masterpieces, and challenging their competitors just like engineers do in real life.

We live in a society where our children's hoped-for outcome for a gift received is that it be accompanied by the legend "No assembly required". That way they can get started playing with it, tiring of it, and laying it aside.

Even when some assembly is required, we want it to be minimal, so we can get on with "programming" and running it.

Creating from scratch is a messy business, but when students truly work to create something themselves, and are eager to match their product against others in competition, there is a sense of accomplishment that is profound and invigorating, and they learn a lot about themselves in the process.

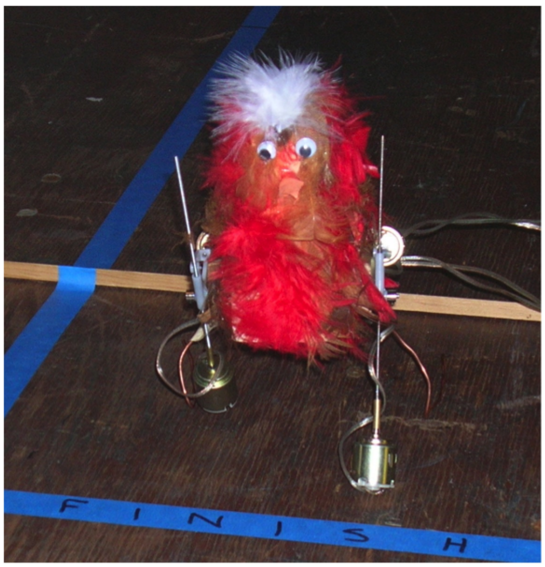
There are other benefits to this route. If kits contain just basic materials, they can be very inexpensive,[1] and therefore accessible to many more students; secondly, students have the challenge of cutting, sawing, drilling, painting and putting together everything themselves, where the results, whether good, or not so good, will influence the performance of the resulting product. Whether that product becomes an artistic walking robot, or any other product is quite immaterial compared to the experience of taking responsibility and holding to a schedule for the final result.

When the process has been developed and supported by a technical organization such as the Institute of Electrical and Electronic Engineers (IEEE),[2] students have the added benefit of interacting with large numbers of professional engineers who are pleased to share their time and experience with them, knowing that these students will represent the future of their profession. They devote their time to guiding the students at no charge, further keeping down the cost to the students and the schools.

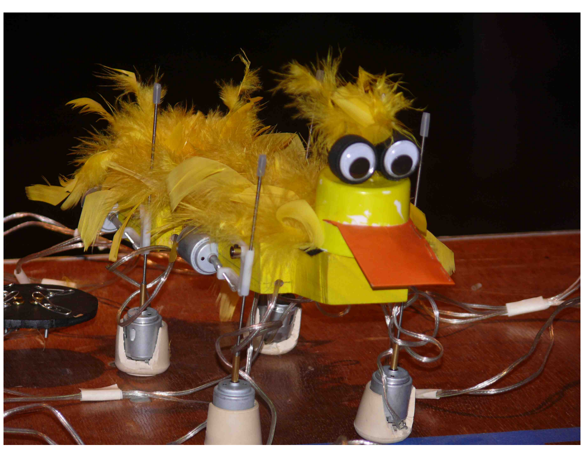
No profession is free of report writing and formal presentations, so a 35 page written report and an oral presentation is required and represents 40% of the final score. This results in a teaching process that is fun and affordable to every school.

One of the teachers who has run this project will be speaking to you later about it, but meanwhile lets look at some pictures of the robots and the kits from which they were made.

We'll begin with the 2-leg walking robots. They have 2 powered legs and 2 skids, and the robot body becomes the creation of the team, who must be sure that it does not inhibit the operation of the robot.




Notice that it requires creativity but no great cost to come up with something original and fun. In the next picture we see another creation with feathers, but this time we have a 4-leg robot.



Both of these robots were built from scratch from a $49 kit in the case of the 2-leg robot, and two $49 kits in the case of the 4-leg robot.

The student teams start by shaping the robot body from a block of wood, and the control units from a piece of plywood. They learn to read drawings, lay out and cut the parts with precision, work with power tools, assemble the parts and learn to make the robot walk and climb over obstacles. The kit is shown below:

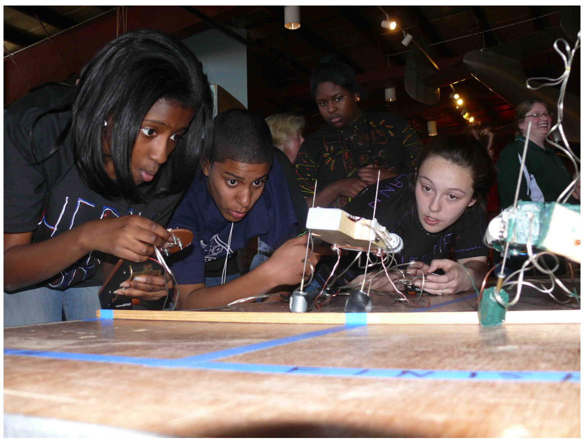

**So how do the students learn to think like Engineers?**

Its not the robot, it's the process of building, making mistakes, and learning from them. Because of a design purposely intended to be unreliable unless built perfectly, things go wrong throughout the process, and the students learn to resolve the problems, using what they have learned in their academic science and math classes, and the experiences they have encountered throughout the process. With discrete teacher input and guidance, they will become prepared to handle the things that will go wrong during the competition and the interactive Oral presentations that are held afterwards with a panel of engineers.

Good teamwork is the key to success as it is with any engineering project.

**The Performance Run**

The competition is tense but friendly, with 2 teams at each table. It's the equivalent of what an engineer does after developing a prototype and having a team of observers determine how its performance compares to that of its competition.



Walking the robot requires motions similar to those we use when walking, yet we are no longer conscious of them. Students need not only a well-built robot, but must also re-learn to apply skills they learned as toddlers when they first started to walk. For a 4-leg robot, its learning how a 4 legged animal moves. It takes a few days to master these skills, particularly as the robots have to climb over two hurdles to complete the course.

It should be noted that each student operates just one leg and this requires good teamwork to insure that their 2 or 4 minds work together.

Judges not only measure the time for each team to complete the course, but observe how many times they touch its robot, either because it has fallen over or its mechanism has jammed. They also score the interaction between team members when crises occur.

**The Oral Presentation**

As mentioned earlier the Oral Presentation is held immediately after the Performance Run, and the panel of judges evaluate both the effectiveness of the presentation and their teamwork, the material presented, the creativity of the robot body and shipping container, and the workmanship and quality of the soldering of all electrical connections. This is the equivalent of the engineers' presentation to their customer seeking approval to release the prototype for production.

**The Artistic Component**

No engineered product is complete without its artistic component – in fact most domestic vehicles and appliances would be un-marketable unless they were artistically pleasing – so the design of the robot body is an integral part of the process, and points are awarded not just for the appearance, but its practicality, logic and humor.

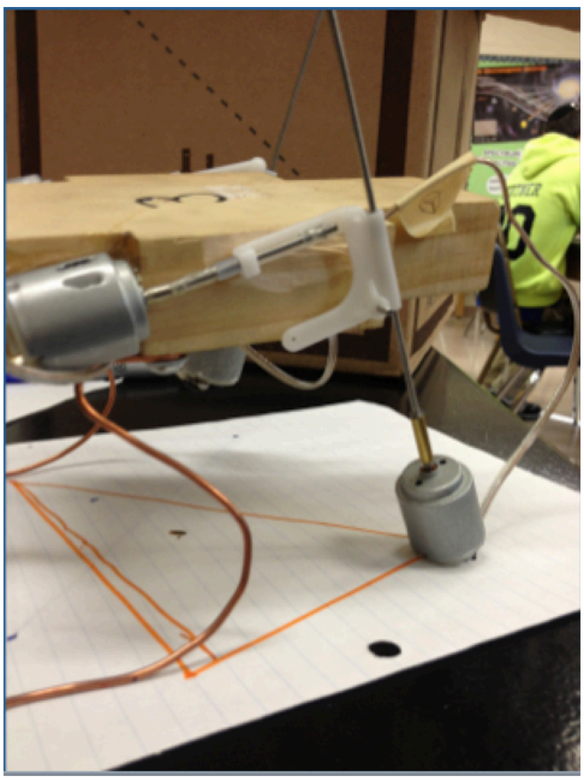
**The Written Report**

In this age of communication, reports are part of our daily lives, so the students use their experience to prepare a 35 page Written Report that will be judged along with all the other features described above.

The written report includes bios of the team members, a description of the work performed, schedule objectives, problems encountered, how the robot has performed at school, costs, problems resolved, a copy of their log book entries, sketches and photographs, and details of their attempts at automation if the team has chosen to add this option. This is comparable to the report submitted by an engineer seeking funding to develop a new product.

**The Design. Why a walking robot was selected for this exercise.**

The design is extremely simple with each robot's leg being the hypotenuse of a triangle and the radius of an arc. The other sides of the triangle represent the vertical and horizontal distances moved and the force vectors that act on the leg as it propels the robot body forward.



Triangles can also be used to determine the center of gravity and stability of the robot and prevent it from falling forward or backwards. This allows many math and physics concepts to be used and brought into a practical application.

Switches are made up of a combination of paper clips and brass fasteners, and they move the foot of each leg Up, Forward, Down or Back in a sequence that must be developed by each team.

Couplings are simply plastic tubing, acting alone when a flexible coupling is required such as when linking a horizontal motion with an arc, or encased in a brass tube when a rigid coupling is required.

Every component has been selected to provide function and low cost.

**Options for students seeking greater challenge.**

After a first year of familiarization a teacher may opt to offer his or her teams additional challenges. They can build themselves a programmable controller that will automate the actions the students learned when they operated the robot manually, or they can purchase or lease an IEEE developed programmable controller board, that is similar to an Arduino™ board, but with the additional features needed to run their robot as either an open loop or closed loop autonomous system.

These techniques can be applied to either 2-leg or 4-leg robots, and are some of the innovative options that are introduced each year. Other options include building part of the robot using a 3-D printer.

While automation makes certain functions easier, students are challenged to learn ways to operate an otherwise brain-controlled adaptive robot (with manual control), then using a programming language (C++) frequently used in industrial applications to operate it autonomously in the uncertain situations the robots will encounter at the competition.

Teams selecting these options are required first to operate manually for the Performance Run, then make additional runs in Open Loop and Closed Loop mode. While there are additional costs for these options, every effort has been made to keep their cost low and accessible.[3]

**Teacher familiarization and responsibilities.**

Teachers become very involved in this learning process, though they've found it takes about 3 years to develop the best combination of academic instruction and the management of the project. We generally advise not trying autonomous operation until at least a year of building manually controlled robots.

Two training programs are provided for teachers and mentors at the Baltimore Museum of Industry, one in November and the other in January. This project is one of the 12 Engineering Challenges supported by this institution.

**Conclusion and Benefits.**

Students tell us they like the process and the competition; Teachers say they find the Written Reports and the Oral Presentations very helpful. Most important is that the final score is the sum of 28 metrics that are an objective measure of how each team has performed in this state-wide STEM project; and the results have been used in some schools in lieu of a final exam. Members of outstanding teams can describe their achievement on their college applications, and in some cases have been awarded scholarships based on their performance.

All students benefit from the experience, particularly since there are so many different tasks involved that every member of the team feels like they have made their own very special contribution. Just as engineers trouble-shoot and take on a range of responsibilities in a project, these students evaluate the *different* strengths of the various members of the team, and figure out how to optimize each of the tasks and follow them through to obtain the best overall results.

In this way the students are indeed working like engineers, and the scores are indicators of how effective this has been./

*Bibliography:*

[1] ***Cost of Robot kit****/s for Manually controlled Robots (includes necessary parts, manuals, participation in Robot Challenge, replacement parts and mentor services – does not include the "D" cell flashlight batteries, which we recommend should be provided by the students).*

- *First 2-leg Robot Kit per school (for 2 to 4 students): Free*
- *Subsequent kits for 2-leg Manually operated robots (most popular item): $49*
- *Kits and manuals for 4-leg robots (for 4 to 8 students): $88*

*It typically takes 21 hours to prepare a 2-leg robot for the competition, about 25 hours for a 4-leg robot.*

[2] ***Institute of Electrical and Electronic Engineers (IEEE)***

*IEEE is the world's largest professional association, with 430,000 members worldwide, dedicated to advancing technological innovation and excellence for the benefit of humanity. Among other activities it works with industry, universities, and government to raise students' literacy in science, math, engineering, and technology.*

*With 4500 members in the Baltimore Section, and an active organization that holds regular monthly meetings on many topics of interest, the Robot Challenge is one of the programs directed at helping high school students improve their STEM skills.*

*The Robot Challenge was developed in Baltimore, and about 300 students participate each year, about half of whom are girls. Over 70 of its engineer members support this activity, acting as mentors, judges, scorekeepers and photographers. All are volunteers.*
*The Robot Challenge is also held at two locations in the State of New Jersey. Other locations are being considered.*

[3] ***Options for students seeking greater challenge***

*The operation of the Robot can be enhanced by using a Programmable Controller (a mini-computer) to control the 4 movements of each leg autonomously (8 motions for a 2-leg robot, up to 16 motions for a 4-leg robot).*

*Two kits are available for doing this, and the steps can be programmed in a sequence and with motor running times determined by observing the robot walk under manual control (these steps are known as "drive by time"). One of the kits can also be programmed to control the operation of each leg movement until it reaches the end of its trajectory (known as "drive until indicated").*

*Autonomous operation is more complex but is likely to be more consistent than manual control, though it may be less responsive to the small disturbances that can be encountered during the Performance Runs. The "drive until indicate" mode (using end-stop switches) is more responsive to changes than the "drive by time" mode, but has more devices that can go wrong.*

*We recommend that the most sophisticated students attempt all 3 runs, in Manual Mode, Timed Mode (known as Open-loop control), and End-Stop Mode (known as Closed-loop control), and determine which mode gives them the best results. Bonus points are awarded for automation runs.*

***Programmable Controllers:***

*For students wanting the challenge of building the Controllers themselves,*
*we offer the Classic Kit:*
*• Kits and Manuals for Classic 2-leg Automated: $89*
*• Kits and Manuals for Classic 4-leg Automated: $118*
*These controllers are built up on a breadboard, and since everything is assembled and wired by the students, it provides a good introduction to electronics. It uses software known as BASIC, but due to physical limitations, cannot be used to operate the robot in Closed-loop mode. The controllers take about 10 hours to build and check-out, and the parts and wires cannot be re-used.*

*For those wanting to automate the robot using a pre-built and tested Controller, we offer a:*
*• Re-usable Industrial 2-leg Automated Controller: $165*
*One-year lease: $89*
*• Re-usable Industrial 4-leg Automated Controller: $240*
*One-year lease: $118*
*These controllers are "state-of-the-art", use C++ software, and can be used for both*
*Open-loop and Closed-loop control. Though they are re-usable year after year, they do require a new Automation accessory kit each year (after the first), and will require an End-Stop Feedback Control accessory kit to operate in Closed-Loop mode.*

*• Automation accessory kit for 2-leg Industrial Controllers (first year free): $10*
*• Automation accessory kit for 4-leg Industrial Controllers (first year free): $15*
*• Accessory kit for 2-leg End-Stop Feedback Control: $34*
*• Accessory kit for 4-leg End-Stop Feedback Control: $49*

**Consult our web-site for more information: [www.robotchallenge.com](http://www.robotchallenge.com)**

**Or contact us directly at Nevilleed@aol.com**