WELLS FARGO

Graham Robertson

ROV Curriculum

UNDERWATER ROBOTICS (ROV) Teachers Guide and Curriculum

"...to transform our culture by creating a world where science and technology are celebrated and where young people dream of becoming science and technology leaders."

— Dean Kamen, Founder First Robotics.

About the teacher:

Ideally you will have an engineering or science or tech background, and be a problem solver, but . . . really just the ability to keep ahead of the students and be able to guide the design, construction and testing of the ROV. Many resources are available to help besides this curriculum.

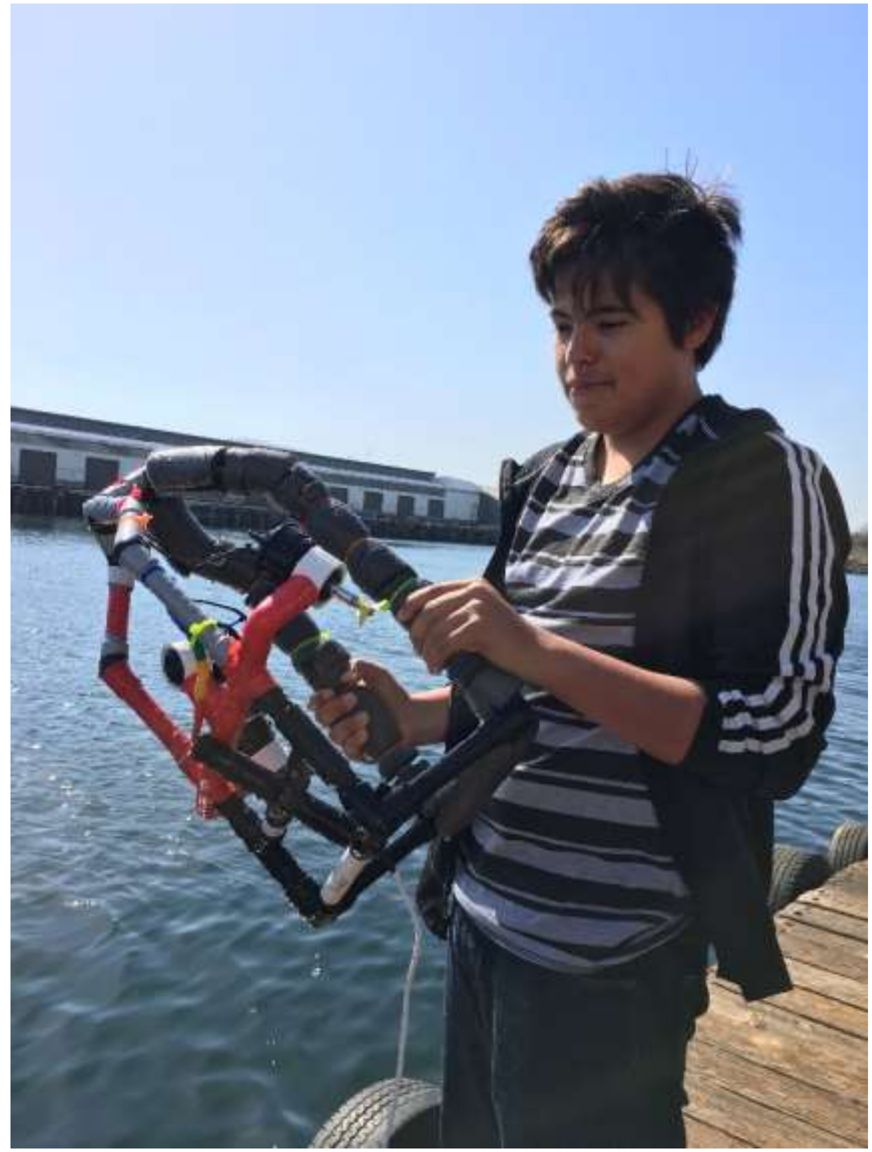
Failure for the students is not an option – it is essential! If students are not making mistakes, then there is too much cookbook step by step instruction, and not enough challenge.

Here are some Ideas from the Mindset kit, developed at Stanford University.

- Many students shy away from challenging schoolwork and get discouraged quickly when they make mistakes. These students are at a significant disadvantage in school—and in life more generally—because they end up avoiding the most difficult work.
- Successful entrepreneurs make more mistakes and learn from their mistakes.
- Making mistakes is one of the most useful ways to learn in math. Our brains develop when we make a mistake and think about the mistake. This brain activity doesn't happen when people get work correct.
- To see similar videos about growth mindset, watch this TEDx Talk by Dave Paunesku, founder of PERTS (which created the Mindset Kit). You can also sign up for Professor Jo Boaler's course, How to Learn Math, and check out youcubed.org.

PROGRAM LENGTH

This curriculum was designed for 6th to 8th grade students, with 12 class meetings one day a week after school, 2 hours per session (with snack break) incorporating two field trips.
Students with more STEM experience or MATE supplied kits will require less time.



TEAMS
To design and build their ROV, students with varied skills, attention spans, design experience, and ability to be an independent learner have to be in a team. Teams can be self-selected after several sessions, or assigned by the mentor.

CAREERS

The students will learn about Engineering careers, learn skills such as soldering and shrink wrapping, and understand electric circuits, buoyancy, and other scientific principles, design and build a simple ROV, then participate in a mini Mate competition. For the first 4 sessions, the first 20 minutes of each class was spent introducing science, engineering and design principles.

<u>Field trips to local engineering companies will provide an invaluable look at real world careers and innovation.</u> (In Los Angeles we went to BlueRobotics and Altasea),

If field trips are difficult to arrange, available Videos online show commercial ROV use. The MATE website has excellent links.

TECHNICAL RESOURCES

There are several great resources for the technical side of building the ROV. Two organizations hold regional, national and international ROV competitions, based out of Monterey Peninsula College and MIT

Marine Advanced Technology Education (MATE) https://www.marinetech.org/home/

The Marine Advanced Technology Education (MATE) Center is a national partnership of organizations working to improve marine technical education, and in this way help to prepare America's future workforce for ocean occupations. Headquartered at Monterey Peninsula College (MPC) in Monterey, California, the MATE Center has been funded as a National Science Foundation (NSF) Advanced Technological Education (ATE) Center of Excellence since 1997.
The MATE Center also receives funding from NSFs Innovative Technology Experiences for Students and Teachers (ITEST) program and the Reseach Experiences for Undergraduates (REU) program. Additional support comes from industry sponsorships and SeaMATE store sales.

SeaPerch

SeaPerch began as one project in a book entitled "How to Build an Underwater Robot," by Harry Bohm and Vickie Jensen. There were many projects in the book, and SeaPerch captured just two pages, with a parts list and instructions on how to assemble the vehicle. Years later, Professor Thomas Consi at MIT developed a curriculum around the SeaPerch as a way to grow the Ocean Engineering Program at MIT. Seeing the possibility of using SeaPerch to train teachers, MIT's Dr. Chryss Chrystostomedes sought funding from the Office of Naval Research (ONR) and the MIT Sea Grant office and began to train teachers in the Boston area and beyond. Several years later, The Society of Naval Architects and Marine Engineers (SNAME) had the vision to utilize its resources to manage the program and partnered with The Office of Naval Research (ONR) to take the SeaPerch Program from what was essentially a teacher-training program and develop it into a national K-12 STEM Outreach program. Through a grant from ONR, SNAME created a program that could be national in scope, including creating a kit, infrastructure, supporting materials, website, ordering and inventory mechanism, and a network of individuals to help grow the program. The efforts began to take root, the program grew to include almost all 50 states to date, and a national competition, the National SeaPerch Challenge, continues to expand yearly.

Since 2011, SeaPerch program has been managed by RoboNation (The Association of Unmanned Vehicle Systems International Foundation - AUVSIF), and continues to expand nationally.

RISENET

Both organizations have curriculum ideas and training videos on their websites. The Miami Science Museum, in partnership with MATE, has produced an excellent "build your own" ROV set of directions for Risenet, and uses readily available parts, or MATE sells for $140 the ROV in a bag set of components.

To build their own control box, shown in the foreground, using the Rise description, students need 3 DPDT momentary switches, (pack of 5 for $15 on Amazon) and 3 bilge pumps (about $10 each on Amazon) and tools listed in the last page of the Miami Museum, or Mate, or SeaPerch guides.

A recommended but more expensive route is to purchase complete Pufferfish kits from Mate, $200 unassembled or $260 with an assembled control box. https://seamate.org/collections/rov-kits/products/seamate-pufferfish-rov-kit-rev-7?variant=70247677968

For beginner students, the unassembled angelfish control box is $65, and the switches are soldered individually, where the pufferfish kit has the switches soldered directly to the printed circuit board. https://seamate.org/collections/rov-kits/products/3-seamate-angelfish-control-box kit?variant=16507023429

The Pufferfish control box is in the foreground. The girls are using an Intex 10 foot wide by 30" deep pool, about $90 on Amazon.

Safe 12 volt power can be provided with the Mate 12 plug in supply [https://seamate.org/collections/power-related-products/products/12v-dc-power-supply-w-powerpole-outlet-gfci for $160](https://seamate.org/collections/power-related-products/products/12v-dc-power-supply-w-powerpole-outlet-gfci), or a battery jump starter can be used, and will power several ROV's at once for a session at the pool.

Mate sells a powerpole adapter package for $35. Shown was a simple connection by cutting the insulation off the connector, being careful to do the red and black in separate locations so they cannot short, then hooking on the battery clips from the power supply.

Standards based. This ROV design and construction curriculum covers requirements of the following state and national standards.

Next Generation Science Standards. Sixth – Eighth grade Engineering Technology and the Application of Science standard MS-ETS 1 Engineering Design.

California Department of Education

Next Generation Science Standards for California Public Schools, Kindergarten through Grade Twelve

Grade Six – Integrated Course

Standards Arranged by Topic

California Department of Education

Clarification statements were created by the writers of NGSS to supply examples or additional clarification to the performance expectations and assessment boundary statements.

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

**California clarification statements, marked with double asterisks, were incorporated by the California Science Expert Review Panel.

The section entitled "Disciplinary Core Ideas" is reproduced verbatim from *A Framework for K–12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas*. Revised March 2015.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K–12 Science Education*:

Connections to other DCIs in this grade-band: **MS.LS2.A** (MS-LS1-4),(MS-LS1-5)

MS Engineering Design

MS Engineering Design

Students who demonstrate understanding can:

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K–12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Asking Questions and Defining Problems Asking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models. ▪ Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints,	**ETS1.A: Defining and Delimiting Engineering Problems** ▪ The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (MS-ETS1-1)	**Influence of Science, Engineering, and Technology on Society and the Natural World** ▪ All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ETS1-1) ▪ The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and

including scientific knowledge that may limit possible solutions. (MS-ETS1-1) **Developing and Using Models** Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. ▪ Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. (MS-ETS1-4) **Analyzing and Interpreting Data** Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. ▪ Analyze and interpret data to determine similarities and differences in findings. (MS-ETS1-3) **Engaging in Argument from Evidence** Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world. ▪ Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-ETS1-2)	**ETS1.B: Developing Possible Solutions** ▪ A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4) ▪ There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3) ▪ Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3) ▪ Models of all kinds are important for testing solutions. (MS-ETS1-4) **ETS1.C: Optimizing the Design Solution** ▪ Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (MS-ETS1-3) ▪ The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)	by differences in such factors as climate, natural resources, and economic conditions. (MS-ETS1-1)

Connections to MS-ETS1.A: Defining and Delimiting Engineering Problems include:

Physical Science: MS-PS3-3

Connections to MS-ETS1.B: Developing Possible Solutions Problems include:

Physical Science: MS-PS1-6, MS-PS3-3, **Life Science:** MS-LS2-5

Connections to MS-ETS1.C: Optimizing the Design Solution include:

Physical Science: MS-PS1-6

Articulation of DCIs across grade-bands: **3–5.ETS1.A** (MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3); **3–5.ETS1.B** (MS-ETS1-2),(MS-ETS1-3),(MS-ETS1-4); **3–5.ETS1.C** (MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3),(MS-ETS1-4); **HS.ETS1.A** (MS-ETS1-1),(MS-ETS1-2); **HS.ETS1.B** (MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3),(MS-ETS1-4); **HS.ETS1.C** (MS-ETS1-3),(MS-ETS1-4)

California Common Core State Standards Connections:

ELA/Literacy –

RST.6–8.1	Cite specific textual evidence to support analysis of science and technical texts. (MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3)
RST.6–8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-ETS1-3)
RST.6–8.9	Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ETS1-2),(MS-ETS1-3)
WHST.6–8.7	Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-ETS1-2)
WHST.6–8.8	Gather relevant information from multiple print and digital sources **(primary and secondary)**, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. **CA** (MS-ETS1-1)
WHST.6–8.9	Draw evidence from informational texts to support analysis, reflection, and research. (MS-ETS1-2)
SL.8.5	Integrate multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. (MS-ETS1-4)

Mathematics –

MP.2	Reason abstractly and quantitatively. (MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3),(MS-ETS1-4)

At our first class meeting, students introduced themselves, and on their nametag had written their prospective career. They talked about their life goals and career goals. After everyone had spoken, I asked them to talk about how robots could do their future job! Fun discussion, and it led into discussing skills they had and would need to develop.

General outline: a structure that you can modify to suit your students.

2 weeks

Career opportunities, introduction to Physics, practice soldering –
3 students per soldering iron kit, practice boards to learn soldering before tackling the ROV switches. (Kits to build a digital clock or AM radio or flashing lights are on Amazon, etc). Introduction to electric circuits.

Many students will have no idea about conductors, insulators, circuits, fuses etc. If they are simply told what to do, without an experiential basis, they will not develop a deep understanding.

6 weeks

Choose teams - **build ROV's** with simple reversing switches and bilge pumps. (each ROV will cost about $60 for 3 motors plus controller). **1/2" PVC PIPE** is sold in big bundles at home stores for under $30. The appropriate corners can be bought too, or use the plastic parts from the Mate kits.

Students will design, measure and cut the pipe (lots and lots of cutting!) Attaching the motors, getting the weight and flotation right, and waterproofing connections will be difficult and all of the ROV's may not work completely. Must have access to a pool or a testing tank.

Field trip to Blue Robotics or another engineering company. Engineers could come over for one of the construction weeks to help the kids.

Field trip to Altasea or aquarium or other marine organization.

4 weeks

Teams will complete the control box, tether attachment, power supply connection and test their ROV to **compete in a mini-Mate competition**
Culminate with a competition day in the pool.

Week 1

Introductions. What is an ROV?

Show BlueRobotics intro video or other https://www.youtube.com/channel/UC3XeiPLt1JTutx7nyYn2Tzg

What is an Engineer? Free discussion should end up somewhere at applied science – **Build cool stuff.**

An aerospace friend decided to explore down – How much of the Earth is covered by water? He started a company called SEAmagine

https://www.youtube.com/watch?v=9VOqpSNGgYI

Out with the Soldering Iron kits. If students have never soldered, they will need to know how to use wire strippers, clean the iron,

SAFETY RULE ALWAYS PUT A HOT IRON BACK IN THE STAND. ASSUME ANY IRON IN A STAND CAN BURN YOU!

Make a circuit that runs a bilge pump through a switch. Make a circuit with several different colored wires, soldered and shrink wrapped.

https://www.youtube.com/watch?v=Qps9woUGkvI or demonstrate. Let students make mistakes rather than giving too much instruction.

Week 2

Circuits. Great analogy to water flow https://www.youtube.com/watch?v=8jB6hDUqN0Y&list=PLp8XAEWVecCvsMtD1onNtb-1R0qw7Wk7I&index=7&t=17s

Fuses This is fun!

1. Go outside or on a fireproof surface, and use a 12 volt battery power pack to send electricity through a 22 gauge wire connected between the battery clamps. Safety Glasses.
2. Turn on the current only when it is safe.

3. The wire should catch fire – like a toaster only it will melt.

4. Have a team solder in a fuse holder in the series circuit. Select a low amp (10) fuse. Turn on the power – the 22 gauge wire is fine. Disconnect the battery and have students examine the burned out fuse.

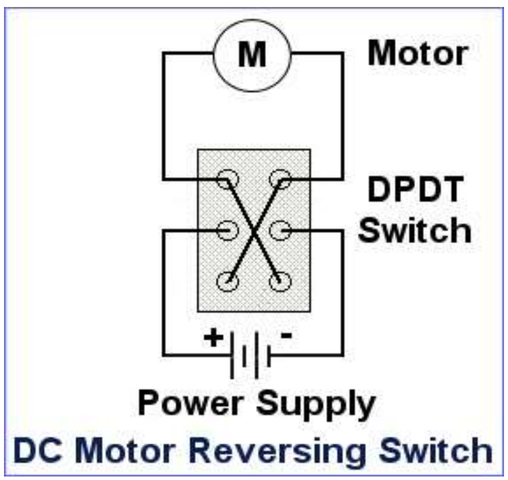
5. Try again with a bigger fuse. Same result. There is no resistance load, so the fuse will blow as too much current flows.

6. Ohms law written V/R = I Ask what happens to I if R is small. Use a multimeter to measure the resistance of the short 22 gauge wire. And calculate the current. Poof, the fuse will blow!

7. Measure the resistance through a sump pump. Choose a fuse based on the V/R calculation, plus a margin, and put the pump in water, then turn on the 12 volts. Success, and the fuse will prevent any accidental shorts or overloads from causing damage.

Reversing Switch

Each control box needs 3 reversing switches, two for the 2 forward/reverse thrusters, and one for the vertical thruster

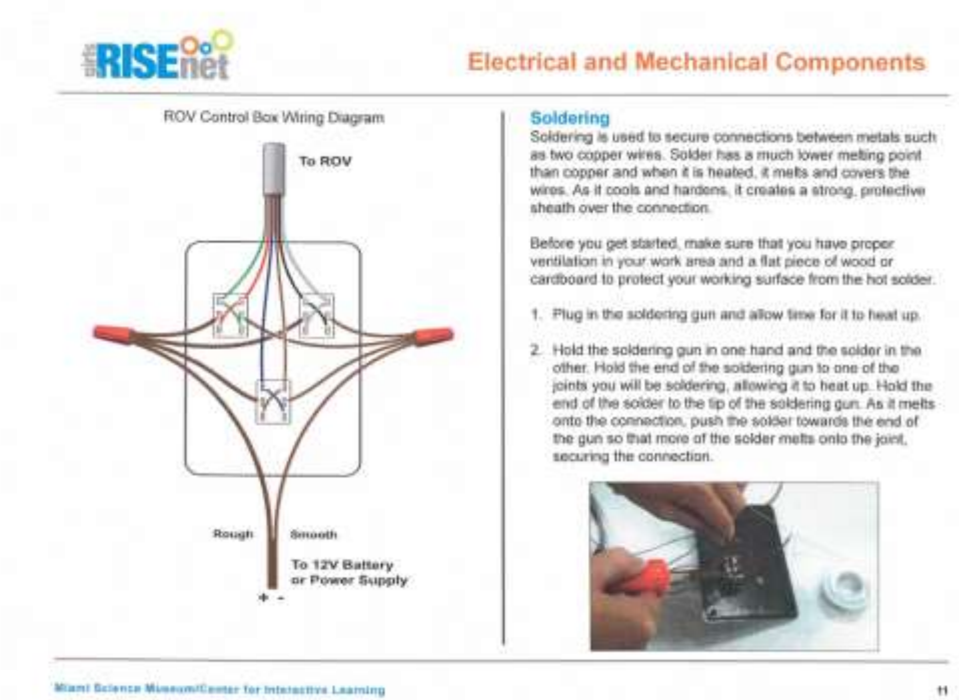


The "X" connecting the four output terminals of the switch is the key. Cutting, stripping and soldering the 3 "X" connectors per team may be an attention span challenge for younger students, but the solder joints must be done well!

RISEnet from Miami Science Museum, a MATE partner, has produced an excellent guide to building an ROV that is available through the MATE website.

https://www.marinetech.org/files/marine/files/Curriculum/Other%20Curriculum%20Resources/RiseNet%20Intro%20to%20ROVs%20Learning%20Card_Final.pdf

here is the key page for wiring the control box. Refer to pages 3 to 15 for the complete method to build and wire the controller.



RISEnet

Electrical and Mechanical Components

ROV Control Box Wiring Diagram

Soldering

Soldering is used to secure connections between metals such as two copper wires. Solder has a much lower melting point than copper and when it is heated, it melts and covers the wires. As it cools and hardens, it creates a strong, protective sheath over the connection.

Before you get started, make sure that you have proper ventilation in your work area and a flat piece of wood or cardboard to protect your working surface from the hot solder.

1. Plug in the soldering gun and allow time for it to heat up.
2. Hold the soldering gun in one hand and the solder in the other. Hold the end of the soldering gun to one of the joints you will be soldering, allowing it to heat up. Hold the end of the solder to the tip of the soldering gun. As it melts onto the connection, push the solder towards the end of the gun so that more of the solder melts onto the joint, securing the connection.

Miami Science Museum/Center for Interactive Learning 11

Week 3

Cut required holes for the control box. We chose to use the larger, cooler rectangular switches. Round holes for the cheaper switches are so much easier! We used an oscillating saw with the round blade shown below, and the students loved marking, cutting and filing the opening. I bought 3 switch plastic mounts that slid into the openings.

I made a practice box at home, but students were able to drill holes in the class

with a regular hand drill. I used an impact driver – again, this was a new and exciting experience for the students.

Week 4

Visit by Bluerobotics engineers. Note the Intek pool.

https://youtu.be/aO19SvuFrBA

Continue building the controller

Week 5

The tether is made from Cat 5 ethernet cable. Use patch cord style, as it has multiple small wires and is flexible. The cable designed for in ground or in wall is solid core wire and very brittle and too hard to work with.

Week 6

Play with PVC. Buy a lot extra so they can make mistakes – I know, they should plan carefully . . .

Week 7

Now they have to cut the PVC to put in mounts for the thrusters and the connector cable.

I let them be proud of their excellent measurements and work before pointing out their mistakes!

Week 8

Buoyancy testing in the pool

We used 16d galvanized nails for ballast, then some students tried sand. The nails won! Foam pipe insulation is excellent for flotation.

If student controllers were not working, we allowed them to use MATE Pufferfish controllers. One big problem that we were not able to solve was that the propellers come off when the students go from full speed ahead to abrupt reverse.

Other than not doing thi abrupt change in speed, the solution is to use different propeller suppliers, bilge pumps, or Arduino based controllers which require new expertise.

Week 9

Field trip to engineering company. In Los Angeles, we went to Bluerobotics. Amazing.

Students have learned enough about engineering skills to appreciate the details of design and production of cool devices.

Week 10

Pool testing. Plan tasks for the Mini MATE competition.

Week 11

Final rush to have a working ROV ready for the ocean.

Week 12

MATE at the ocean. Final problem solving and fun!

Parts List

- Chuanganzhuo Backup Camera RCA Video Cable,CAR Reverse Rear View Parking Camera Video Extension Cable with Detection Wire (10M/33FT)
- In Stock
-
$8.99

- Car Backup Camera, Esky Waterproof Starlight Rear View Night Vision HD CMOS 170 Degree Vehicle Reversing Universal Car Backing Camera
- In Stock
$18.99

- Esky 7 inch TFT LCD Color 2 Video Input Car Rear View Monitor DVD VCR Monitor with Remote and Stand

$36.99

- [MAIYUM 63-37 Tin Lead Rosin Core Solder Wire for Electrical Soldering (0.8mm 100g)]
  $8.99

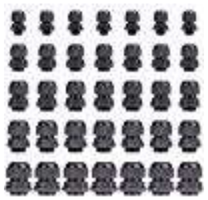
- Elenco Two IC AM Radio Kit | Lead Free Solder | Great STEM Project | SOLDERING REQUIRED
  $16.99

- Shoreline Marine Bilge Pump 600 GPH
  $9.70

- Baomain Female quick disconnects Vinyl Insulated Spade Wire Connector Electrical Crimp Terminal 16-14 AWG 6.3mm Blue 100 Pack
  $6.69

- Ginsco 580 pcs 2:1 Heat Shrink Tube 6 Colors 11 Sizes Tubing Set Combo Assorted Sleeving Wrap Cable Wire Kit for DIY
  $6.99

- Nilight 10 Pack NI-FH01 Inline Holder 14AWG Wiring Harness ATC/ATO 30AMP Blade Automotive Fuse Holder-10, 2 Years Warranty
  $8.99



- Cable Gland Nylon Plastic Waterproof Adjustable, Cable Glands Joints Wire Protectors- Pg7, Pg9, Pg11, Pg13.5, Pg16 35pcs
  $8.99

 WGGE WG-015 Professional crimping tool/Multi-Tool Wire Stripper and Cutter (Multi-Function Hand Tool)$7.99

- Soldering Iron Kit Electronics, Yome 14-in-1 60w Adjustable Temperature Soldering Iron with ON/OFF Switch, 5pcs Soldering Iron Tips, Desoldering Pump, Tweezers, Stand, Solder, PU Carry Bag
  $13.59

- Knoweasy PVC Cutter Pipe Cutter,Tube Cutter for Cutting Less Than 1-5/8in(42mm) O.D. PEX,PVC,and PPR Pipe,Plastic Tubing Cutter Ideal for Plumbers,Home Handy Man and More
  $16.99

- WATERWICH 7 pin Momentary Winch In Out Rocker Toggle Switch Waterproof DC 20A 12V/10A 24V Black Shell/ON-OFF-ON DPDT illuminated Rocker Switch For Auto Truck Boat Marine (Red)
  $8.99
  or

- RuoFeng DPDT Toggle Switch AC 125V 6A Amps ON/ON 6 Terminals 2 Position Pack of 10
  $9.39

- Hook up Wire Kit (Stranded Wire Kit) 22 Guage (6 different colored 25 Foot spools included) - EX ELECTRONIX EXPRESS
  $14.99

- YXQ 120x120x90mm Clear Cover Junction Box IP65 Waterproof ABS Enclosure Cable Project Case (4.7 x 4.7 x 3.5 inches)
  $10.99

Intex 10 Foot x 30 Inch Round Metal Frame Backyard Above Ground Swimming Pool $94.99

- Velleman MK101 Flashing Led Sweetheart
  $8.31

- GlowGeek 100pcs Assorted Auto Car Truck Standard Blade Fuse Assortment 2A 3A 5A 7.5 A 10A 15A 20A 25A 30A 35A Car Boat Truck SUV Automotive Replacement Fuses
  $9.98

- [25 pack 15 Amp ATC Fuse Blade Style Scosche 15A Automotive Car Truck]
  $5.95

- Amazing GOOP 170011 Marine Adhesive, 3.7 Fluid Ounces
  $6.99

- TYUMEN 100FT 18 AWG Gauge 2 Conductor Stranded Red Black Car Home Stereo Speaker Audio Cable Electrical Hookup Wire - 99.95% Oxygen Free Copper Wires
  $21.99