2020

Aquabots Student Build Manual

A GUIDE FOR BUILDING THE STANDARD AQUABOTS ROBOT

AUTHOR: JESSICA WILKES

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Contents

Aquabots Build Manual 3
Introducing Aquabots 3
Getting started – What you Need 4
Step 1: 1
Step 2: 3
Step 3: 4
Step 4: 5
Step 5: 6
Step 6: 8
Step 7: 9
Step 8: 10
Step 9: 12
Step 10: 13
Step 11: 14
Step 12: 15
Credits and Acknowledgements 16
Photos and images 16
Acknowledgements: 16

Aquabots Build Manual

Introducing Aquabots

NZ AquaBots is an underwater robotics programme for school-aged children in New Zealand. Teams are formed from Years 4 – 13 students. The aim is to inspire students, help discover the next generation of Kiwi scientists and engineers, while introducing potential engineering and robotics careers.
Teams work together to build an underwater robot which is capable of completing the year's challenges. These challenges include an obstacle course, and several activities which require collection and delivery of a range of items. The final challenge is a presentation to demonstrate what they have learnt.

Thanks to our sponsors
This activity would not be able to happen without the sponsorship of the following companies and organisations
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Getting started – What you Need

Tools

- Eye protection (optional)
- Ruler/tape measure and pen
- Hacksaw
- Wire strippers
- Needle nosed pliers
- Electric hand drill
- Vice
- ¼" Drill bit
- 3/32" Drill bit
- Soldering iron
- Craft knife
- Scissors
- Disposable Gloves

Materials

- 1.8 m or 6x 1 foot lengths ½" PVC pipe
- 10x ½" PVC elbows
- 4x ½" PVC tees
- Pool noodle
- Electrical tape
- Masking tape
- 15 m CAT 5 Tether Cable with RJ-45 Connector Installed on one end
- 3x 35 mm Film canisters, with caps
- 3x 12-Volt DC motors
- 3x Propellers
- 3x 4-40 Threaded propeller shaft Couplers
- 3x 4-40 Tee nuts
- 3x 4-40 Lock nuts
- 1x Super glue
- 1/3x Wax bowl ring

Other Resources

- Newspaper
- Waste paper
- Paper towels
- Electronic device (laptop, tablet)
- Camera
- Coloured paper
- Pens
- Pencils
- Rulers

Curriculum Links:
Level 2: Use appropriate units and devices to measure length

Level 3: Use linear scales and whole numbers of metric units for length

Level 4: Use appropriate scales, devices and metric units for length

Convert between metric unites using whole numbers and commonly used decimals

Level 5: Select and use appropriate metric units for length

Convert between metric units using decimals

Level 6: Measure at a level of precision appropriate to the tasks

Key Competencies:
- Using language, text and symbols

Vocabulary List:
- Inches
- Convert
- Measure

Items and equipment you need:
- Tape Measure/Ruler
- Pen
- PVC pipe
- Hacksaw
- Vice

We can now:
- Use a device to measure accurately
- Guide a teammate through measuring lengths of pipe
- Cut out all our pieces of pipe

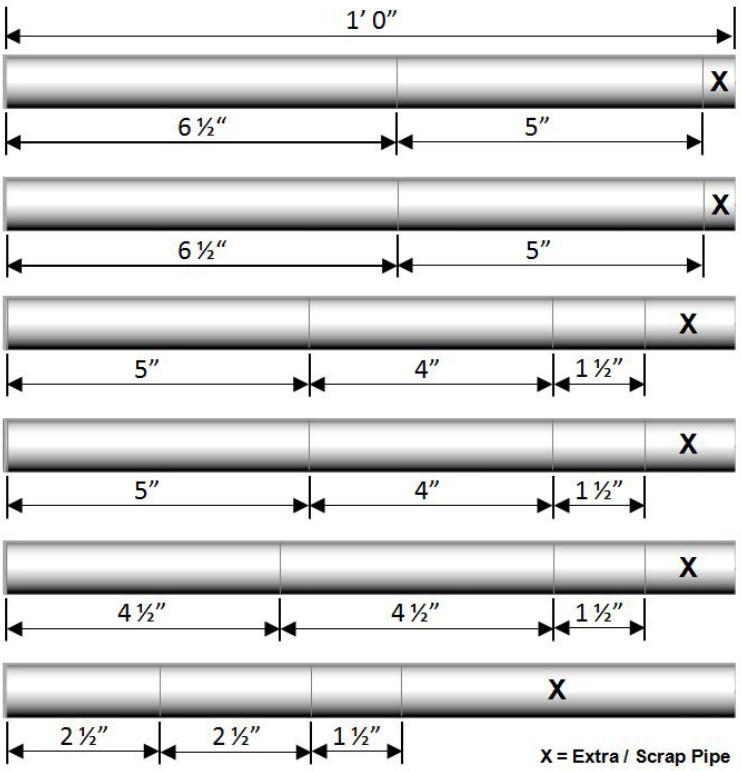
Step 1:

Measure and label the pieces of pipe to match the list below

List of Pieces you Need

Use the check list to make sure you have measured out all your pieces of pipe.

- ☐ **Two** Pieces – **6.5”** (16.5 cm) long
- ☐ **Four** Pieces – **5”** (12.7 cm) long
- ☐ **Two** Pieces – **4½”** (11.4 cm) long
- ☐ **Two** Pieces – **4”** (10.2 cm) long
- ☐ **Two** Pieces – **2½”** (6.4 cm) long
- ☐ **Four** Pieces – **1½”** (3.8 cm) long



ADULT - check that each group/team has all the pipes correctly measured and labelled before proceeding.

Review Health and Safety for Using Hacksaws:

1. Put the pipe into the vice
2. Ensure that the line to cut is approximately between 2cm and 5cm from the edge of the vice
3. Keep hands away from the blade
4. Make straight cuts with the blade – keep the blade straight
5. Rest your other hand on the vice to provide balance

Have teams cut all their pipe pieces out. Get them to double check that they have all the right pieces.

COMMON ERRORS

- Students will measure the inches as cm instead e.g. 6.5cm = 6.5"
- Students will try to arrange the measurements in a different way than the pipe diagram
- Students will forget to measure a piece of pipe
- Students will measure a measurement on top of another one, i.e. 16.5cm with a 10cm marked on it as well

NB: if pipes are 1cm out they are ok, if they are several centimetres out they need to be recut

Curriculum Links:
Level 2: Build their language and develop their understanding of the many ways the natural world can be represented

Explore every day phenomena such as forces

Seek and describe simple patterns in physical phenomena such as floating and sinking

Level 3: Explore, describe and represent patterns and trends for everyday examples of physical phenomena such as forces

Level 4: Explore, describe and represent patterns and trends for everyday examples of physical phenomena such as forces

Level 5: Identify and describe the patterns associated with physical phenomena found in simple everyday situations involving forces and movement.

Level 6: Investigate trends and relationships in physical phenomena such as forces and movement

Investigate how physics knowledge is used in a technological application

Key Competencies:
- Relating to others

Vocabulary List:
- Density
- Buoyancy
- Mass
- Weight
- Volume
- Chuck
- Fluid

Items and equipment you need:
- Drill
- Large drill bit
- Elbow connectors
- Vice
- Masking Tape

We can now:
- Use a drill safely
- Use the connectors to build out robot
- Explain why an ice cream container with ice cream in it will float, but an empty ice cream container with holes in it will sink
- Use the right words to describe why something sinks

Step 2:

Drilling Holes in Your Elbows

Using the masking tape put three pieces about 2 cm long across the bend in the elbow. This will help the drill bit to dig in and get a grip.

Place the elbow in the vice and tighten – careful to ensure that it only holds it securely not squashing it.

COMMON ERRORS
- The drill bit slips on the pipe
- The drill bit falls out
- They drill through both sides of the elbow

Review Health and Safety for Using Drills:

1. Never drill anything in your hand
2. Always use the vice
3. Press down as you drill
4. Press the trigger slowly till the bit has gripped
5. Keep hands out of the way
6. Take finger off the trigger immediately if you feel unsafe or the drill slips

Place the drill vertically and slowly press the trigger. When the drill bit has really dug into the pipe (not just the masking tape) then speed up the drill. Ensure that you press down so the drill drills into the pipe.

Stop once it has gone through the pipe.

Curriculum Links:
Level 2: Build their language and develop their understanding of the many ways the natural world can be represented

Explore every day phenomena such as forces

Seek and describe simple patterns in physical phenomena such as movement

Level 3: Explore, describe and represent patterns and trends for everyday examples of physical phenomena such as forces movement

Level 4: Explore, describe and represent patterns and trends for everyday examples of physical phenomena such as forces

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Level 6: Investigate trends and relationships in physical phenomena such as forces and movement

Investigate how physics knowledge is used in a technological application

Key Competencies:
- Relating to others

Vocabulary List:
- Force
- Velocity
- Friction
- Motion

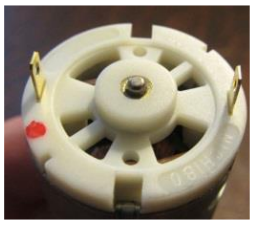
Items and equipment you need:
- Motors
- Electrical Tape
- Scissors

We can now:
- Connect our motors to the cable
- Explain how motors make our robot move and the effect of water on our motors

Step 3:

Tape Up Your Motors

Use your marker to colour in the gold connector that is next to the red dot.



COMMON ERRORS
- Colouring in both gold connectors
- Not taping the top of the motors
- Layering more than one layer of tape

Use the electrical tape to tape all-round the side of the motors. Then cutting pieces of tape, tape across the top of the motor. Tape across the bottom of the motor so that the wax cannot get in.

Curriculum Links:
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Explore every day phenomena such as electricity

Seek and describe simple patterns in physical phenomena such as electricity

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Investigate how physics knowledge is used in a technological application

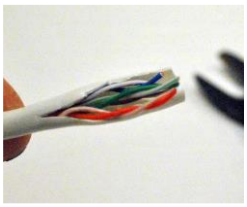
Key Competencies:
- Managing self

Vocabulary List:
- Electricity
- Electrons
- Circuit
- Voltage
- Amps

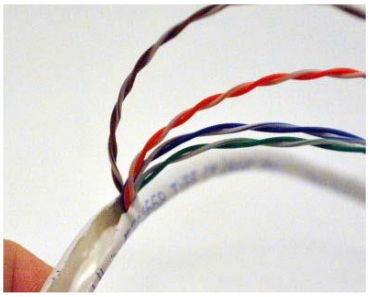
Items and equipment you need:
- Ethernet cable
- Wire strippers
- Scissors/craft knife

We can now:
- Connect our motors to the cable
- Explain how electricity moves around the circuit

Step 4:



Strip Your Wires
Use the wire strippers to cut through the Ethernet cable to expose the four wires inside.



Review Health and Safety for Using Craft Knives:

1. Never cut anything in your hand
2. Hold the cable in place with your fingers
3. Cut away from you
4. Cut small pieces at a time
5. Move your fingers out of the way

Use a craft knife to gently cut through the plastic, like gutting an eel. Continue for about 50cm. Then peel the plastic off and cut off.

You should now have four cables.
Cut the brown one off at the same point you cut the plastic off. We do not need this wire.

Strip the coloured plastic off each of the cables so that approximately 2cm of copper wire is exposed.

COMMON ERRORS
- Cutting all the way through the copper wire
- Stripping too much of the plastic off the copper wire
- Not stripping enough of the plastic off the copper wire
- Only having one strand of copper wire
- Cutting off any wire except the brown one

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Investigate how physics knowledge is used in a technological application

Key Competencies:
- Thinking

Vocabulary List:
- Terminal
- Film Canister

Items and equipment you need:
- Film canister
- Ethernet cable
- Drill
- Battery
- Controller

We can now:
- Test our motors
- Explain why our motors go

Step 5:

Drill your canisters + thread wires through
Press the lid onto the canister and hold the canister at the bottom on the table.
It is important that the hole is drilled exactly in the middle of the canister, to allow the motor shaft to go through.

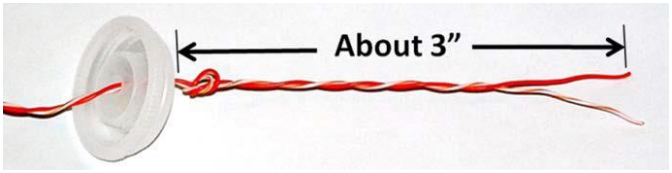
Review Health and Safety for Using Drills:

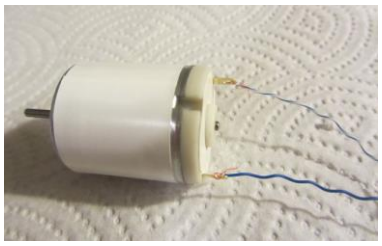
1. Never drill anything in your hand
2. Press down gently as you drill
3. Keep hands out of the way
4. Take finger off the trigger immediately if you feel unsafe or the drill slips
5. Press the reverse switch to pull the drill out of the hole

Drill gently through the lid using a small drill bit. Turn the canister over and drill through the bottom.
Repeat for all the canisters.

COMMON ERRORS
- Threading the wires through the wrong way
- Only drilling one part of the canister
- Using the big drill bit

Take the cable that you have stripped and slide the paired colours through the hole in the lid. Make sure the lid will still close. There should be about 5cm of cable inside the lid, then tie a knot on the inside of the lid.





Take the stripy cable and twist it around the gold connector that is NOT coloured in.
Take the solid cable and twist is around the connector that is coloured in.
Make sure NO plastic is touching the gold connectors

Connect all the motors. Plug the ethernet cable into the controller.
Connect the black alligator clip to the black terminal on the battery and the red alligator clip to the red terminal on the battery.
Test your motors all work.

Troubleshooting if my motors don't go:

1) If none of the motors go

- Have you connected the alligator clips correctly?
- Try a different controller
- Try a different battery

2) If one/two motors don't go:

- Is the copper wired twisted/connected?
- Is there plastic touching the gold connectors?
- Have you connected the solid to the connector that was coloured in?
- Are both wires connected?

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Understand that materials can be formed, manipulated, and/or transformed to enhance fitness for purpose of a technological product

Level 5: Identify and describe the patterns associated with physical phenomena found in simple everyday situations involving electricity.

Level 6: Investigate trends and relationships in physical phenomena such as electricity

Investigate how physics knowledge is used in a technological application

Key Competencies:
- Managing self

Vocabulary List:
- Solder
- Melting point
- Weld

Items and equipment you need:
- Soldering iron
- Solder
- Ethernet Cable
- Motors
- Battery
- Controller

We can now:
- Test our motors
- Explain how electricity pass through the soldered connection
- Explain why plastic in the connection will stop the motors working

Step 6:

Solder your connections

We are going to solder the connection between the ethernet cable and the motors.

Review Health and Safety for Using Soldering Irons:

1. Wait until the soldering iron has heated up
2. Always put the soldering iron back into the stand if you are not using it (that includes when adjusting the motors or solder)
3. If helping stay on the opposite side of the person's writing hand, i.e. if you are helping a left handed person stay on their right hand side
4. Keep a length of around 10cm of solder
5. Wash your hands after soldering
6. Never touch the soldering iron anywhere other than the handle
7. Never muck around with the soldering iron
8. Hold the soldering iron like a pencil

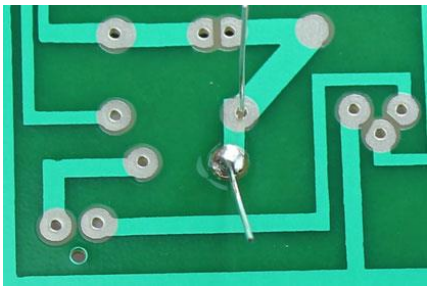
Line up the copper connection and the wire (ensuring that there is NO plastic between these) and rest the solder on the connection.

COMMON ERRORS
- Holding the soldering iron off the connection
- Not feeding the solder in
- Only soldering a small bit of the connection

Bring the soldering iron down into contact with the solder. Feed the solder in as it melts. Ensure that the soldering iron is in contact with the copper connection.

If the solder sticks, simply touch the soldering iron to it and it will melt.

A good solid connection should look like a smooth volcano. Check that the connection is soldered around the whole copper connection. Repeat for all the wires/copper connections.



Test all the connections to make sure that the motors go.

Troubleshooting IF my motors don't go:

1) If none of the motors go
- Have you connected the alligator clips correctly?
- Try a different controller
- Try a different battery

2) If one/two motors don't go:
- Is the copper wire soldered?
- Is there plastic touching the gold connectors?
- Are both wires soldered?

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Investigate how physics knowledge is used in a technological application

Key Competencies:
- Relating to others

Vocabulary List:
- Thrust
- Buoyancy
- Hydrodynamics
- Fluid
- Drag

Items and equipment you need:
- Film canister
- Ethernet cable
- Drill
- Battery
- Controller

We can now:

- Put the robot together
- Explain why we pool noodle
- Explain why the front of the robot is the front

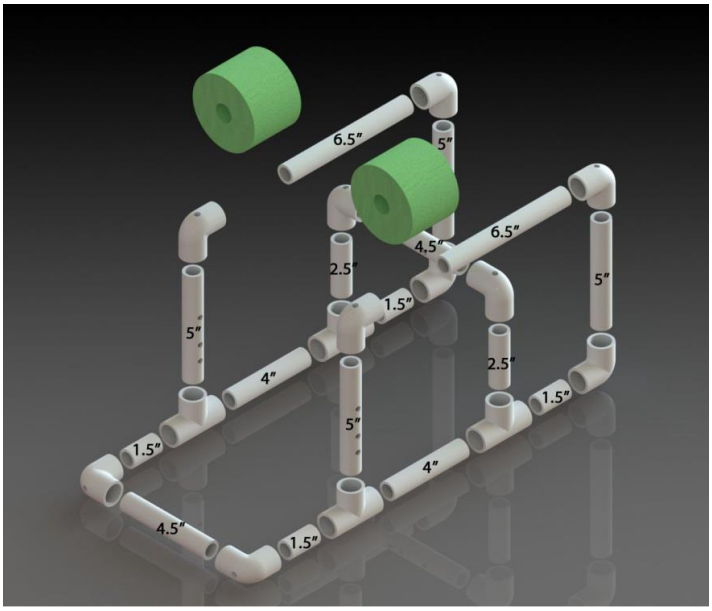
Step 7:

Building Your Robot

Use the image below to put your robot together. Make sure that you press each join together firmly so that it doesn't fall apart. Once you have tested your robot in the pool for the first time you can then superglue joints together if you need/want to.

COMMON ERRORS
- Discovering that pipes are not the same length
- Not putting the pool noodle on

You need to label each pipe with the inches measurement so that you can easily put the robot together. The pipe may need to be firmly pressed through the pool noodle depending on the size of the pool noodle hole.



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Investigate how physics knowledge is used in a technological application

Key Competencies:
- Relating to others

Vocabulary List:
- Waterproof
- Hydrophobia
- Molecule

Items and equipment you need:
- Toilet wax
- Motors
- Film canisters
- Paper towels
- Gloves
- Battery
- Controller

We can now:
- Test our motors
- Explain why our motors will not get wet once in the water

Step 8:

Toilet Wax for Motors

Review Health and Safety for Using Toilet Wax:

1. Put gloves on
2. Keep gloves on until the final test and the lid on the canisters is closed
3. Make sure that there is paper under your working area
4. Don't eat or taste the wax

Take a ball of wax and put it around the end of the motor with the shaft. You should put enough wax on to the thickness of one adult finger.

Gently push the motor into the canister so the shaft pokes through the hole – you may need to turn the motor a little to line the shaft up correctly.

Press the motor down until the shaft fully pokes out of the canister.

Test the motor still works.

Curl up the cable and add wax to the top of the canister to hold the cable in. Fill the top of the motor and press the lid on. There should be no cable hanging out the sides and no empty space between the wax and the lid.

Test the motor to make sure it still works.

COMMON ERRORS
- Not enough wax
- Too much wax
- Wax on the sides of the motors
- Solder connection is broken while putting the wax on/motor into the canister

Troubleshooting if my motors don't go:

1) If none of the motors go

- Have you connected the alligator clips correctly?
- Try a different controller
- Try a different battery

2) If one/two motors don't go:

- Remove the wax and check the connection is still soldered

3) If motors go slowly:

- Hold the controller down for forwards or backwards until the motor moves fast (the wax needs be loosened from the shaft.

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Investigate how physics knowledge is used in a technological application

Key Competencies:
Managing self

Vocabulary List:
- Kort nozzle
- Pitch
- Drag

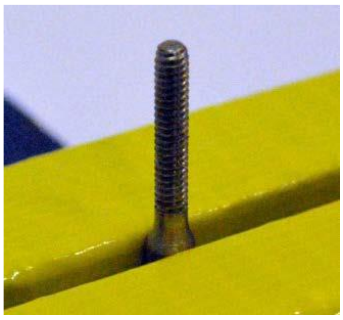
Items and equipment you need:
- Propellers
- Shaft
- Nut
- Hex bolt
- Vice
- Pliers
- Superglue

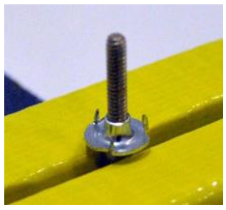
We can now:
- Put the propellers together
- Explain how the propellers move our robot forwards

Step 9:

Putting Your Propellers Together

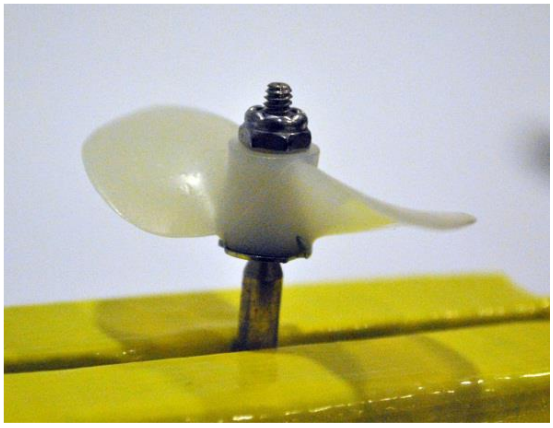
Put the threaded coupler into the vice with the thread face up.





Screw on the nut (which has the points on it) all the way to the bottom. Make sure the points are facing upwards (like in the diagram on the left).

Place the propeller onto the coupler with the groove facing down.



Screw on the nut. NB: It is VERY IMPORTANT that the nut is screwed down until it can go no further. The propeller should NOT spin freely.

When this is done, ensure that the motor shaft is clear of all wax – use an alcohol wipe to clean it, drip a couple of drops of superglue into the hollow end AND onto the shaft. Slide the coupler onto the shaft all the way down.

COMMON ERRORS
- Putting the propeller on upside down
- Not screwing the nut on tight enough
- Testing the motors before 10 mins
- Not cleaning the shaft

Leave to dry for at least 10mins before testing.

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Investigate how physics knowledge is used in a technological application

Key Competencies:
- Relating to others

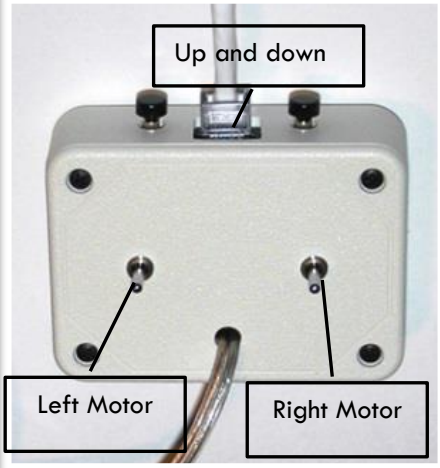
Vocabulary List:
- Hydrodynamics
- Thrust
- Drag

Items and equipment you need:
- PVC pipe robot
- Controller
- Battery
- Motors
- Tape
- Scissors

We can now:
- Put our robot in the water
- Explain why our motors are placed where they are

Step 10:

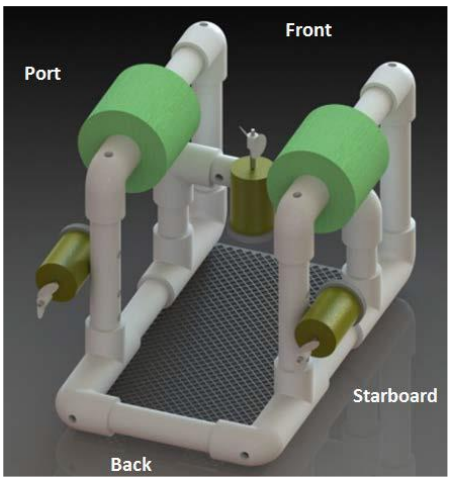
Attaching Your Motors
Test your motors to determine which motor is connected to the up and down buttons on the controller, the left and the right.



Ensure that the left motor is attached to the left of the Aquabot and the right to the right side.

For your motors to be effective you need to determine the best location for your motors.

For the up and down motor you have the choice of placing it propeller up or propeller down. And then you need to choose how high up the shaft you will connect it.
Keep in mind that your propeller needs to be below the water line when it is floating in order to be useful.



For the left and right motors, you need to decide if they will be inside the Aquabot or outside the Aquabot.

Then you need to choose where on the vertical you will attach them. It is important that the motors are level with each other so that you can turn accurately.

It is best to attach your motors with tape to start with. You can later attach them with cable ties or stay with tape. Tape is easier to remove if you choose to move your motors after testing.

COMMON ERRORS
- Not testing which motor is which
- Putting the motors on the front of the robot
- Putting the motors on backwards

Curriculum Links:
Level 2: Develop a plan that identifies the key stages and the resources required to complete an outcome

Level 3: Understand that technological outcomes are recognisable as fit for purpose by the relationship between their physical and functional natures Level 4: Explore, describe and represent patterns and trends for everyday examples of physical phenomena such as electricity

Level 4: Understand that materials can be formed, manipulated, and/or transformed to enhance fitness for purpose of a technological product Level 6: Investigate trends and relationships in physical phenomena such as electricity

Level 5: Understand that technological outcomes are fit for purpose in terms of time and context. Understand the concept of malfunction and how "failure" can inform future outcomes.

Key Competencies:
- Thinking

Vocabulary List:
- Design Process
- Constraint
- Prototype

Items and equipment you need:
- Paper
- Pens

We can now:
- Create our first prototype of our attachment
- State the design process

Step 11:

Ask
The first step is to define the problem. Here you need to review the different challenges. What does your robot have to do?
What are the constraints? This means the rules that you have to operate in. For example, you are not allowed to attach a camera to your robot. That is a constraint. Another constraint is that your robot needs to fit in a 31cm by 46cm x 46 cm box.

1. Read through the rules, challenges and marking schedule
2. Summarise these and explain them to someone else
3. Create an couple of examples of the objects that your Aquabot may have to collect

Imagine
Now that you know what you are aiming for, you need to come up with a range and variety of ways that you could complete the mission.
To start with put all your ideas down.

Now review these ideas, which are realistic, what materials might you need to make it happen, which ones would be the most effective and why?

Select two or three of the best ideas and use these in the next step.

Plan
Create a list of what materials you need – do you need wire, mesh, plastic, metal? Perhaps collect a couple of different material options so that you can have different choices to test.

Sketch out what your attachment might look like – put measurements on the sketch

Use TinkerCAD to create a 3D model of your robot and attachment – you might be able to 3D print this

Create
Make your attachment.
Test it out with your examples that you made of the objects. Feel how heavy it is.
Attach it to your robot and test (more info in the next step)

COMMON ERRORS
- Not reading the description of the challenges
- Not reading the scoring charts
- Making the attachment too long
- Making the attachment too heavy

Create different versions of your attachment using the different materials and the different ideas you had.

Improve
Once you have tested your attachment (see next step), improve it. Consider making it from a different material, positioning it differently, using your pool noodle flotation differently, and measure to make sure your robot is still complying with the rules.

Finally, if it doesn't work go back and **imagine, plan and create** again.

Curriculum Links:
Level 2: Build their language and develop their understanding of the many ways the natural world can be represented

Explore every day phenomena such as electricity

Seek and describe simple patterns in physical phenomena such as electricity

Level 3: Explore, describe and represent patterns and trends for everyday examples of physical phenomena such as electricity

Understand that technological outcomes are recognisable as fit for purpose by the relationship between their physical and functional natures

Level 4: Explore, describe and represent patterns and trends for everyday examples of physical phenomena such as electricity

Understand that materials can be formed, manipulated, and/or transformed to enhance fitness for purpose of a technological product

Level 5: Identify and describe the patterns associated with physical phenomena found in simple everyday situations involving electricity.

Understand that technological outcomes are fit for purpose in terms of time and context. Understand the concept of malfunction and how "failure" can inform future outcomes.

Level 6: Investigate trends and relationships in physical phenomena such as electricity

Investigate how physics knowledge is used in a technological application

Key Competencies:
- Thinking

Vocabulary List:
- Neutral buoyancy
- Buoyancy

Items and equipment you need:
- Robots
- Craft knife
- Battery & Controller
- Attachment

We can now:
- Practice with our robot
- Complete our presentation
- Explain why we removed pool noodle

Step 12:

Testing in the Water – First Visit
The aim of the first visit is to achieve neutral buoyancy. They need to fully submerge the robot and wait til the bubbles are gone. Then see if it sinks/floats and can go up/down. They then need to take pool noodle off – SAVE the pool noodle for later.

COMMON ERRORS
- Cutting off too much pool noodle
- Not fully submerging the robot
- Placing a very heavy attachment on the front/back
- Propellers fall off (wait 10 mins with superglue usage)

Repeat this process. IMPORTANT, every time they MUST fully submerge the robot. Eventually they will have cut off almost 1/3 of the pool noodle.

They can cut the pool noodle lengthwise or vertically, they can experiment and consider the effect on hydrodynamics.

Testing in the Water – Second Visit
The aim of the second visit is to achieve neutral buoyancy WITH an attachment and ensure that when picking up objects the robot is balanced.

Remember to fully submerge the robot when testing buoyancy. Teams may need to add additional pool noodle or reposition pool noodle.

Testing in the Water – Third and Subsequent Visits
The aim for the third and any subsequent visits is to practice collecting objects and navigating the obstacle course. Students should ensure that they take photos and video of their practices and note changes they make based on their tests.

Credits and Acknowledgements

Photos and images

Step 1:
Image 1 – Sea Perch Build Manual
Image 2- clipart-library.com

Step 3:
Image 1 – Sea Perch Build Manual

Step 4:
Image 1 – Sea Perch Construction Manual
Image 2 - Sea Perch Construction Manual

Step 5:
Image 1 - Sea Perch Construction Manual
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Step 6:
Image 1 – manufacturingstories.com

Step 7:
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