We will rock you 3.0

Aquabots Technical Report

Section 1: Abstract

This technical report highlights the design, testing, and performance of the Aquabot, an innovative underwater robot created by the “We Will Rock You 3.0” team. The Aquabot's unique small design emphasises speed, agility, and versatility, featuring a compact, rounded structure that minimises water resistance and allows precise manoeuvring. Key elements include powerful rear-mounted motors attached using 3D printed motor mounts, a blue network cord for enhanced visibility, and modular components such as hooks and nets for task-specific adaptability. By achieving neutral buoyancy through carefully placed floatation aids, the Aquabot demonstrated exceptional stability and control. Through an iterative design process, the team optimised the bot for competition tasks such as navigating obstacle courses, retrieving objects, and clearing debris, showcasing a balance of engineering creativity and functionality. This report reflects the team's focus on innovation, problem-solving, and continuous improvement, laying the foundation for future advancements in Aquabot design.

Section 2: Task overview

Task 1: Obstacle Course

Our Aquabot design is smaller than previous designs so it can manoeuvre through the hoops with more speed and be more agile when it turns. This is important as the task requires the Aquabot to manoeuvre through hoops with speed and accuracy. The smaller design allows more space to pass through the hoops with ease. The surfaces of the Aquabot are rounded which creates a pathway for the water to move past it. Our network cord is painted blue so we can see it against the bottom of the pool so it is easily visible to prevent tangles.

Task 2: Mitigation of Flooding

Our Aquabot is strong and the motors are powerful enabling it to push the L joints up to raise the houses which is necessary to complete this task. As it is small it can easily manoeuvre to each object and the power of the motors allows for fast turns. Using either the hook or the strong corners the Aquabot is able to push the corflute windows up to raise the flags (second objective of the task). Size of the Aquabot was important because drivers are able to use either the hook or the corner of the Aquabot, leading to greater success.

The third part to this challenge involves the Aquabot locating and raising the 3D boxes to the edge of the pool to get maximum points. The hook is strapped to the side of the Aquabot to allow greater manoeuvring through the turns while also maximising the pickup opportunities. Having the motors at the back of the Aquabot ensures it can rise to the surface after picking up the boxes.

Task 3: Prevention of Flooding

This task requires objects to be retrieved from the pool floor using a net or hook attachment. The net at the bottom of the Aquabot, along with the hook and the rear of the bot will all be used to collect trees and sediment and bring it to the top of the pool. Having multiple attachments enables drivers to collect in a variety of ways from the pool bed to ensure maximum success. The Aquabot size allows for manoeuvring around the pool bed as well as tight turns to line up with the trees and sediment to be collected. Additionally this task requires PVC pieces to be transported from the side of the pool and fitted into holes in a structure on the pool bed. Two hooks attached to the Aquabot at the top (in front) will be used to transport these pieces to the pool bed. Using the agility of the Aquabot, including being able to turn efficiently, it will then line up with the structure before placing as required.

Section 3: Design Approach

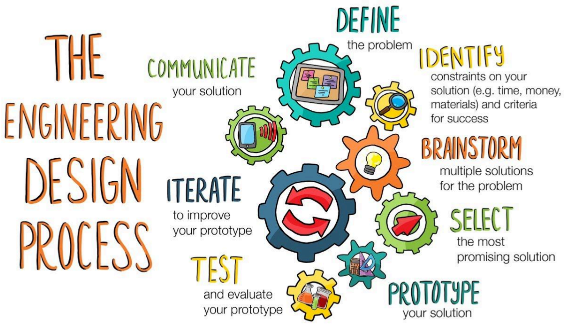

Image 1. The Engineering Design Approach

The team followed the engineering design process as detailed in Image 1 (Science Buddies, 2002 - 2004; YouTube, 2017). The steps of this approach are:

Identify the goal. After studying the competition details, the team agreed the goal was to make an Aquabot which was effective, agile, fast, responsive and that all team members would be able to drive. The Aquabot also would need to be capable of picking up objects and pushing levers.

Identify constraints and success criteria. The team understood that a successful Aquabot would be able to complete the three tasks in the shortest amount of time. The team was also restricted on costs (maximum expenditure of $20) and what equipment was supplied as part of the standard kit. This meant the team had to think carefully about what size Aquabot to create as well as objects to include in their design and what was most needed e.g. hooks and net.

Brainstorm. This is where the team thinks of as many ideas that could solve the problem or are related to the topic. After regionals, where the team used the standard Aquabot (refer Image 2), a brainstorm was created which included the following ideas:

- A way of attaching the motors that didn't use tape or zip ties to make them more secure and stable for consistent propulsion (Kiddle Encyclopedia, 2024)
- Different places to mount the motors on the Aquabot
- Making the Aquabot smaller so that it could turn and move quicker in the water
- Using a 3D printer to create parts
- Changing the colour of our network cable so it is more visible
- Location of pool noodles to enable the centre of gravity to be in the middle for stability
- Adding a different hook to collect items
- Not having a net to create less drag
- Keeping the Aquabot the same size so that it could collect heavier objects

The team discussed all these options in detail before moving to the next stage.

Select. This stage has the team choosing an idea or ideas from the choices presented during the brainstorming. From all the brainstorming ideas, the team ranked what they felt was the most important with the new design focusing on speed and agility and the Aquabot's capabilities of completing all the tasks. Using the experiences of the regional competition they decided on the following four items as most important:

- A way of attaching the motors using a 3D printer
- Adding a different hook to collect items
- Making the Aquabot smaller so that it could turn and move quicker in the water
- Location of pool noodles to enable the centre of gravity to be in the middle

Prototype. The team created a model to trial and test out using the best ideas from the 'select' process. They created using the ideas previously selected, carefully considering the advantages and disadvantages as detailed below in Table 1 (refer Image 3):

	Advantages	**Disadvantages**	**Justification**
Attaching the motors	• More hydrodynamic in the water • Easier to attach • More placement	• Cable management is harder • Having enough clearance between the motor and the mound	Using 3D printed attachments increases the structural integrity between the pipe and motor with an advantage of using less pipe. Structural integrity is the force that our Aquabot can withstand while completing tasks (YouTube, 2022). Greater accuracy of motor placement

	options on the Aquabot		provides consistent and reliable thrust.
Hook attachments	• More options with picking objects up • Additional options for pushing eg corflute windows	• Not as hydrodynamic • Offsets the centre of gravity	A hook is necessary to collect objects but it is important to maintain the centre of gravity in the middle of the Aquabot to ensure it doesn't become unbalanced making driving difficult. Relocating pool noodles to offset the weight of the hook achieved a stable inertia.
Size of Aquabot	• Agile and fast • Sharp turning	• Not having mass to push objects • Weight disadvantage when picking objects up	A smaller Aquabot enables it to accelerate quicker, which can help it to turn faster, move faster through the water and achieve results in a quicker time. This ensures it has a more stable centre of gravity and a reduction in water resistance (Science Learning Hub, 2022)..
Centre of Gravity	• Move with ease and flexibility • Not having to stop and readjust	• Can be easily offset eg. ripples in the water	Inertia explains how hard it is to move an object from point A to B, influenced by its centre of gravity (AEMT Ltd, 2024). An Aquabot with a good centre of gravity enables it to be more balanced and therefore moves the bot quicker through the water.

Table 1. Advantages and disadvantages of brainstorm ideas

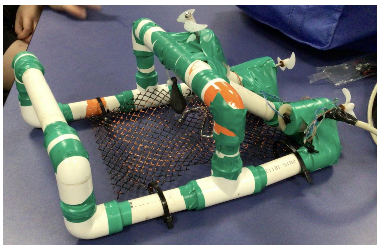

Image 2. Aquabot design used at Regionals

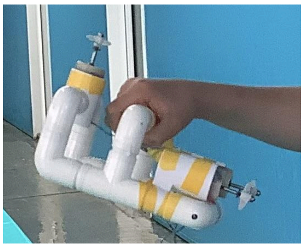

Image 3. Prototype design (Version 1)

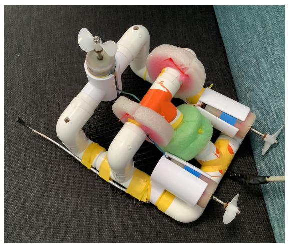

Image 4. Prototype design (Version 4)

Test. During this stage of the design process, the team tested their prototype to make sure everything works well and achieves the purpose. Results of the testing of different versions are summarised below (refer Images 3 and 4).

Version #	**Design modifications**	**Results from Testing**	**Changes made following testing**
Version 1 & 2	Smaller design, no pool noodles	• Sank to the bottom • Wouldn't drive to the top • Would roll from side to side	• Added pool noodles • Retaped motors for greater security • Added more pool noodle
Version 3	Smaller design, pool noodles, hook	• Could move through the water • Could pick up objects • Would tip to the hook side regularly	• Added a net • Adjusted existing pool noodles
Version 4	Smaller design, adjusted pool noodles, hook & net	• Achieved neutral buoyancy • Could move through the water quickly • Could pick up objects from a variety of angles/approaches • Was agile on turns • Responded to controls efficiently and accurately	• Added zip ties to the pool noodles to keep them in place • Continual testing to ensure structural integrity, acceleration and hydrodynamics in the water

Table 2. Design modifications and iterations

Iterate: Based on the results of the testing, the team made changes to ensure the Aquabot worked as was intended (as detailed in Table 2). These modifications included adding hooks and a net and ensured they were placed correctly so the Aquabot did not tip. There was also some movement with the centre of buoyancy to ensure neutral buoyancy was achieved. Additionally, weight was added to the centre to achieve neutral buoyancy. This step took several attempts to get it correct.

Section 4: Experimental results

Objective: To achieve neutral buoyancy meaning that the Aquabot moves fluidly through the water and is responsive to controls efficiently. Neutral buoyancy is when an item neither sinks to the bottom or floats to the top when immersed in water (Seaperch, 2024).
Hypothesis: If we balance the pool noodles to the weight of the Aquabot it will achieve a stable centre of gravity and move through the water in a straight direction.
Analysis: Testing in 1.5 metres of water, with the pool noodles in a variety of positions, the Aquabot moved differently depending on the positioning of the noodles.

These results are summarised in Table 3 below:

Position of Floatation	Performance of Aquabot in water to a depth of 1.5 metres	Analysis
Front of the Aquabot, next to the vertical motor	• More buoyant at the front than the back • Front would tip up • Would not drive in a straight line given a constant angle	Sufficient pool noodles but not located in the right place. Decision made to move the pool noodles to the middle.
Middle of the Aquabot, at the top	• Aquabot tipped backwards due to the weight of the back motors • Would drive in a straight line given a constant angle • Tipping impacted the control the drivers had of the Aquabot	Sufficient pool noodles but placed in the right location. Decision made to leave some poodle noodles in the middle but relocate some to the back of the Aquabot.
Middle and back of the Aquabot	• Aquabot tipped slightly backwards due to the weight of the back motors (less so than before) • Would drive in a straight line given a constant angle • Tipping impacted the control of the Aquabot but less than before	Placement of the pool noodles was correct but not sufficient at the back of the Aquabot. Decision made to add additional noodles.
Middle and more added to back of the Aquabot	• Neutral buoyancy achieved; no tipping when driving • Would drive in a straight line given a constant angle • Good control and response from the Aquabot	

Table 3. Floatation placement and results

Conclusion: Results have shown that floatation added to the middle and back of the Aquabot balanced the weight of the motors, giving the Aquabot neutral buoyancy. The amount of floatation added was extremely important because insufficient floatation would lead to sinking/tipping and adding too much would mean the Aquabot wouldn't dive into the water.

Objective: To move quickly and accurately through the water, achieving fast acceleration from starts or turns.
Hypothesis: A smaller Aquabot will be more agile through the water as it creates less drag/resistance as well as accelerating faster during starts or turns.
Analysis: The team made comparisons between our initial standard design bot (refer Image 2) and our smaller designed Aquabot (refer Image 4), documenting the results in Table 4 below. Testing occurred in a pool with a width of 4 metres, length of 10 metres and a depth of up to 1.5 metres.

Aquabot	**Up & Down** (Time to bottom of pool)	**Time to complete width of the pool**	**Time to complete one length**	**Time to complete obstacle course** (5 hoops)	**Time to retrieve 2 hoops**
Larger Aquabot	18 seconds	45 seconds	1 minute 30 secs	7 minutes 13 secs	1 minute 47 secs
Smaller Aquabot	5 seconds	25 seconds	1 minute 5 secs	3 minutes 18 secs	38 secs

Table 4. Results of bigger vs small Aquabot

Conclusion: The smaller Aquabot was able to move in all directions through the water at a faster speed and more efficiently. It was able to retrieve objects from the pool bed faster, in part due to its increased acceleration after a turn or collecting an object.

Section 5: Reflection and next steps

Reflection: The team greatly enjoyed collaborating to solve challenges and build the Aquabot, learning the importance of valuing and considering each member's ideas. Achieving neutral buoyancy presented a significant challenge, serving as a key learning experience. During testing, they discovered the necessity of sealing gaps in the PVC pipes and strategically adding floatation noodles to balance buoyancy and stability. Their experiences with Aquabots have prepared them well for future endeavours, enhancing their understanding of the design process, buoyancy physics, problem-solving, perseverance, idea exchange, and teamwork.

Next Steps: The team aims to experiment with a more compact bot design that maintains full functionality. They are eager to leverage 3D printing more extensively, testing various components to enhance structural integrity and improve the Aquabot's hydrodynamic performance in water. Additionally, 3D-printed parts could aid in achieving neutral buoyancy, as they may be lighter than the PVC pipes used this year. Allocating time next year to develop a range of hooking attachments would also be beneficial, allowing the bot to pick up items from any approach angle, thus improving efficiency in experimental trials and competitive scenarios.

Section 6: Acknowledgement

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Section 7: References

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Section 8: Costings

Product	Price	Amount	Total price
Hook	$3.00	1	$3.00
Motor Mounts	$1.65	3	$4.95
Total:			$7.95

Table 5. Costings