# The successful utilisation of aquaponic systems within a school setting

**Matthew Knight** explains what aquaponics is, what to consider and why it is such a great teaching tool for schools

I am often asked *'What is an aquaponic system and why would we want to install one in our school?'* This can be easily answered, but does require close analysis of the school's scientific and ecological aims to be implemented successfully.

We should start by defining aquaponics for those who may be unfamiliar with it. Aquaponics, simply put, is the combination of aquaculture and hydroponics. *Aquaculture* is the process of rearing aquatic species (usually fish) in a controlled environment. *Hydroponics* is the growing of plants in water with a soil-less medium. When you combine these two processes, you feed your fish, which in turn produce waste (ammonia) that fertilises your plants (Figure 1). As it mimics a natural ecosystem, it is a great organic way of sustainably growing produce. The teaching possibilities of such systems are, however, invariably constrained by cost, time and your imagination.

## Aquaponics mimics nature

Aquaponics combines natural components of bodies of water: aquatic animals, bacteria, nutrients, and the plants that subsequently grow in them. Just as in the wild, bacteria break down the waste produced by fish and turn it into food for plants. The plants in turn, remove the harmful chemicals from the water and keep it fresh for the aquatic inhabitants. It is a cyclic system: if external chemicals are added to help the plants the fish will suffer and vice versa. It is for this reason that aquaponics naturally lends itself to organic production.

## Comparing aquaponics with other forms of agriculture

As with any system, there are always advantages and disadvantages. Firstly, compared to traditional soil-based agriculture and hydroponics, the water wastage in aquaponic systems is very low. Aquaponics only uses a tenth of the water of soil-based gardening and less water than hydroponics or aquaculture. Water only needs to be added to the system to replace evaporation. Secondly, it

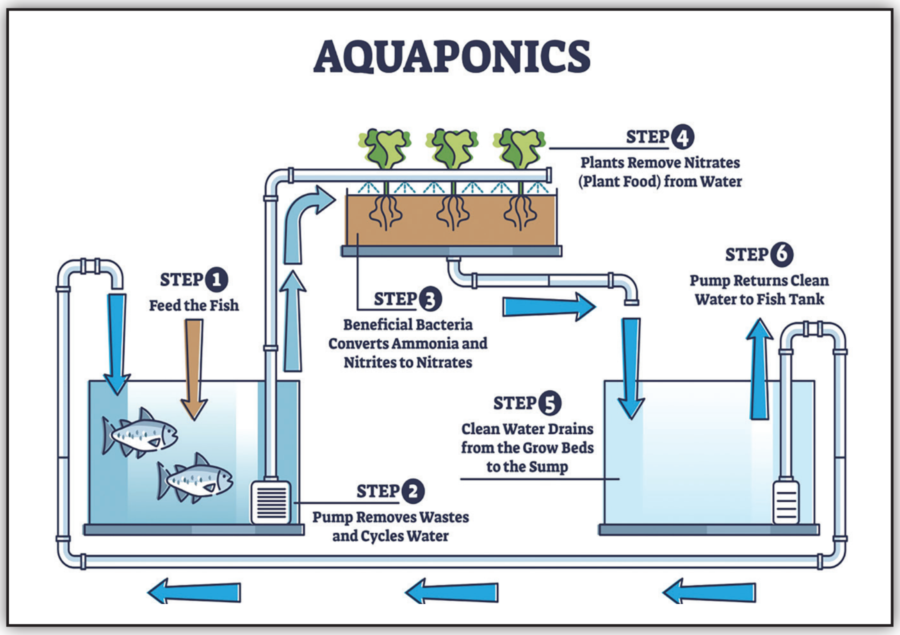


**Figure 1** A media-based aquaponic system

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doesn't require fertiliser or similar products for the plants; the fish do this for you naturally. Finally, plant diseases are drastically reduced as the growing medium used in systems is generally inert.

The major perceived disadvantages are the initial set-up costs and the cost of feeding the fish.

## Costing a system

Aquaponic systems are scalable and therefore the cost varies wildly, depending on the size and location of your project. Indoor projects will tend to be smaller and therefore save cost on holding tanks and growing medium; they will, however, require lighting rigs. A basic indoor system might comprise an old fish tank, a pump, a medium-filled bucket, bell siphon and a cheap LED grow light. Outdoor projects will cost more in growing medium but the trade-off is the reliance on artificial light is negated. A basic outdoor system might comprise a repurposed thousand litre IBC water tank (cut and flipped), growing medium, bell siphon and pump. It should be noted that, although sunlight is great for your plants, it is best kept out of the tanks holding the fish, whether located indoors or outdoors. Due to high levels of nutrients in the water, algae will become rampant if direct sunlight is allowed to penetrate. If you are building an indoor system, blinds or curtains can be utilised to block sunlight. Outdoor systems can either be housed in polytunnels or paint applied to the exterior to prevent light from flooding the tank.

## Choosing the species of fish for your system

Three main considerations will influence your choice of fish. Firstly, the size of your holding tank will restrict what can be kept in it. Check the maximum size of the fish you intend using; aquatic shops should be able to advise you. The second consideration is the temperature of your system; if you are not heating your tank, you will need to stock native cold-tolerant species. The final point is whether you intend to harvest fish for the table. This opens up a moral dilemma for schools; unlike other systems, at my school, Shinfield St Mary's, we chose not to eat the fish in the system. If you don't intend to eat the fish you can use any fish species, such as tench, goldfish, koi, etc. If you plan on harvesting the fish, you can use trout, carp, bream, etc. If you are heating the water, any tropical fish can be used and a popular edible fish is the tilapia, the second most farmed fish in the world after carp (Figure 2).

**Figure 2** Tilapia fish, as used in our inside tank

## Feeding your fish

There are a number of options available. It will of course depend on the type of fish you are keeping. Basic fish food will consist of pellets or flakes; if possible, you should purchase an organic feed (although this will increase the cost). Some enthusiasts also grow and feed chopped earthworms to their fish. If you are feeling adventurous, you could try growing your own BSF (black soldier fly) grubs. These voracious feeders will compost kitchen waste in a matter of hours and fish love them. TV presenter Kate Humble and her husband Ludo promote feeding a combination of worms and BSF to aquaponic fish (Siegle, 2014).

## Example of an indoor aquaponic system

The indoor system we have constructed at Shinfield is media based, heated and LED light powered (Figure 3). Tilapia are fed a vegetarian diet via an automatic timer; they eat the food and naturally produce waste laden with ammonia into the water. Water from the tank is then pumped continuously from the larger fish tank into the small media tank on top. The plants are inserted into an inert clay pellet planting medium. This medium acts both as biological filtration (ammonia converted into nitrates) and mechanical filtration (solid wastes filtered out). The combination of plants and medium remove the majority of harmful nutrients from the water. The plants grow quickly and the fish are kept in clean water conditions. The water continues to rise in the upper tank until it reaches the top of the bell siphon. At this point Bernoulli's equation (used to describe the siphon effect) commences and all water within the vessel is pulled up against gravity and forced down the outlet pipe. The benefit of this system over a simple overflow is that you don't end up with stagnant water at the bottom of the vessel and the roots are regularly exposed to oxygen. We have successfully grown strawberries (pictured) and are now growing an impressive crop of root ginger. This accessible system benefits from being simple and easy to maintain. The main drawback is the cost of lighting and heating the unit, but this is minimised by use of timer switches.

## Example of an outdoor aquaponic system

The second aquaponic system we utilise at Shinfield is located within our school's biodome (Figure 4). This is obviously much larger than the indoor system and incorporates several components. Installed in 2019, we quickly started to experiment with growing different produce. The dome system contains five thousand litres of aquaponics and houses 40 ghost carp and goldfish hybrids. It is powered by a solar panel that stores energy in a battery located inside the dome. We have incorporated three different types of aquaponics within the 20-foot dome. The first (Figure 1) is a media-based system, working in a very similar fashion to the indoor system. The second system is a deep-water culture (DWC) that uses foam rafts that float inside containers filled with filtered nutrient-rich water. Plants are clipped into holes cut in the raft and the roots dangle freely in the water. This is great for growing lettuce, spinach and other green vegetables. Fish waste, and indeed the fish themselves, are kept out of this tank, which helps protect the plant roots. As the roots spend the whole time submerged in water, large quantities of oxygen are pumped into this tank to prevent the roots from rotting.

The final system utilised inside our dome is vertical aquaponics. The beauty of intensive aquaponic farming is that you don't need a lot of space. One of the best methods to maximise space is vertical aquaponics. Plants can be literally stacked on top of each other in tower systems or grown in connected bars (Figure 5). Water is pumped into the top; it then flows through a series of connecting pipes until it reaches the bottom and back into the water tray. This method of growing works really well with strawberries and other plants that do not require support to grow.

**Figure 3** Our basic media-based LED-powered system at Shinfield St Mary's

Being outside creates a whole host of different issues to consider, the largest being temperature fluctuations and exposure to sunlight. In the summer, temperatures can soar to above 40 °C and the plants are bathed in plentiful sunlight. The plants and fish acclimatise well to this extra heat, due in part to the large amount of water being pumped through the system. However, it is vital to keep the fish tanks shaded, as this prevents algal growth. In the winter, temperatures fall in line with those outside. The marked difference is that temperatures generally don't fall below freezing. This requires the growth of native winter vegetables and the reduction of fish feed as they go dormant over the winter period. The next phase of experimentation involves insulation and natural heat and cooling to try to maintain more consistent growing parameters. Ground source pumps and additional

**Figure 4** The Eco-team with Matt Knight inside the biodome at Shinfield St Mary's

**Figure 5** Vertical aquaponic growing inside the dome at Shinfield

ventilation is something we are currently investigating.

The amount of produce that can be grown in such a compact area is truly impressive. There are so many learning opportunities available for children. The main drawback is inherently the cost associated with such large-scale aquaponics. Costs can be kept lower, however, by use of cheaper outdoor structures such as polytunnels and recycling IBCs and other equipment for holding and growing tanks.

## Cross-curricular primary science links

At Shinfield, our sustainability and ecology teaching is based broadly on the 17 UN Sustainable Development Goals. Children learn about the different areas of focus and try to earn badges, demonstrating the completion of the modules. Our aquaponic systems are used as a core to many of these modules. Children from all classes spend six days, across the academic year, working on different projects based around the school. Nine of these goals tie directly into aquaponics: *Zero hunger; Clean water and sanitation; Affordable and clean energy; Industry, innovation and infrastructure; Sustainable cities and communities; Responsible consumption and production; Climate action* and *Life below water.*

Aquaponics is more than just growing food. It teaches children how to live sustainably and how to harness renewable energies. It teaches them the importance of clean water and how it can be achieved. It also naturally lends itself to geography and its associated modules; the water cycle can be modelled beautifully inside these systems. It incorporates large sections of mathematics; for example, when calculating pH levels of water and mapping temperature fluctuations. The opportunities for writing stimuli are also endless: the children have produced some really great, meaningful report-writing based on our systems. Design and technology links exist too: children are often tasked with problem-solving issues that arise within the systems. It also feeds directly into the primary science modules: *Animals including humans* in years 3–6; *Living things and their habitats* in years 4–6.

## Summary

To the newcomer, aquaponics can appear daunting at first. However, with a small investment in time and capital you can create a simple system that will help educate tomorrow's learners. As the demand for food and cultivation rapidly increases, we are faced with learning new techniques to grow produce in a more sustainable way. With the wealth of opportunities available for cross-curricular and scientific learning can you really afford not to embark on your own aquaponic journey?

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UN Sustainable Development Goals: https://sdgs.un.org/goals#goals

**Suggested reading**

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