]cn[**Chapter 6**

]ct[**Farm Urban and Urban Aquaponics**

]cst[**Changing Perceptions in Classrooms and Communities**

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]fl[Rising food and energy prices, increasing unemployment and unhealthy, unsustainable lifestyles are major concerns for today’s society. Aquaponics offers the possibility of increasing food sustainability by low­impact, high­density agriculture at the domestic and community level, reducing transport-related carbon emissions and promoting resilience in the face of supply chain interruptions (Kotzen 2013; Goddek et al. 2015; Cunningham and Kotzen 2015).

Aquaponics combines soil-less growing (hydroponics) with fish husbandry (aquaculture) in an enclosed recirculation system. The combination of growing fish and plants together is not new. Early examples include artificial islands or ‘floating gardens’ in shallow lakes in central America, where plants were fertilised using the mud and waste grudged from the lake bed (e.g. Aztec’s Chinampas 1350–1150 BC) (Turcios and Papenbrock 2014). In this example, however, the presence of wild fish is more or less coincidental rather than designed into the system. Aquaculture of fish in rice fields in South East Asia dates from around 1,500 years ago, and more recently fish have been grown out with rice and other grain production around the world (Coche 1967; Ahmad 2001). A pond, garden and livestock system called the ‘vuon, ao, chuong’ or ‘VAC’ was promoted widely in Vietnam in the early 1980s (Lee Thanh Luu 2001). It is generally accepted that the latest incarnation of aquaponics started in the late 1970s and early 1980s.

Linking aquaculture and hydroponic production in a circular, synergistic way provides an opportunity to address any shortcomings with each. This closed nutrient cycling fulfils the definition of sustainability offered by Lehman et al. (1993), who define sustainable agriculture as ‘a process that does not deplete any non-renewable resources’. Similarly, the cycling nature of the aquaponics system is close to that described by Francis et al. (2003) as a production system resembling a natural ecosystem, with ‘closed nutrient cycles’. Further benefits are gained from reuse of the water via recirculation.

In a simple form of aquaponics, the nutrient-rich waste water from the fish tanks fertilises hydroponic beds. The plants and their associated bacteria remove these nutrients from the water. Uneaten fish feed, fish waste, algae and other organic material in the fish tank water all contribute to this pool of nutrients, acting as fertiliser for the hydroponically cultivated plants. In turn, the hydroponic beds act as a biofilter, stripping toxic ammonia out of the water by providing a suitable environment and large surface area for the ammonia oxidising ‘nitrosomonas’ bacteria and the nitrite oxidising ‘nitrobacter’ bacteria. The cleansed water is then recirculated back into the fish tanks.

Researchers, including Mark McMurtry and Doug Sanders at North Carolina State University (Love et al. 2014), and James Rakocy at the University of the Virgin Islands, developed modern aquaponics systems (Rakocy 1989). Mark McMurtry described the aquaculture system at North Carolina State University as an ‘Integrated Aqua-Vegeculture System’ (McMurtry 1988) consisting of tilapia tanks connected to sand hydroponic vegetable beds. Rakocy at the University of the Virgin Islands developed deep-water aquaponics, where plants are cultured on rafts floating in deep-water troughs circulated with water from fish tanks. McMurtry and, separately, Rakocy note that these aquaponics systems are suitable for use in arid and semi-arid regions where water is scarce and demand for protein and fresh vegetables is high. More recently, there has been a growing interest in aquaponics as an innovative solution to food security (Love et al. 2014). Diver (2006) identified John and Nancy Todd’s ‘The New Alchemy Institute’ on Cape Cod as the earliest developer of integrated fish and vegetable systems. From 1971 to 1991, the institute was ‘a rigorous research farm investigating closing the loop between food production, the built environment and waste’[[1]](#endnote-1) . In an important step in the development of modern aquaponics, the New Alchemy Institute developed the ‘solar pond’ (or solar aquaculture), using the thermal mass of above-ground fish tanks to maintain a more constant temperature in greenhouses (Zweig 1986). A floating hydroponic system was added to this, separated from the fish with a mesh barrier, so that tilapia or catfish could be grown alongside, but separated from, lettuce.

Diver (2006) credits the owners of S&S Aquafarm, Tom and Paula Speraneo, with the evolution of aquaponics into commercial-scale production in the early 1990s. A substantial system of pea-gravel beds and tilapia tanks was used to grow ‘fresh basil, tomatoes, cucumbers, mixed salad greens and an assortment of vegetable, herb, and ornamental bedding plants in the aquaponic greenhouse’. The Speraneos were keen proponents of aquaponics; they produced training materials and opened up the site of their commercial-scale system to visitors. More than ten thousand visitors of all ages visited over its life. Like the S&S Aquafarm, the Freshwater Institute in Shepherdstown, West Virginia, built demonstration aquaponics systems and produced training materials focused on the design and operation of aquaponics systems, including reciprocal hydroponics where the growing media are periodically flooded and drained to supply oxygen and water to the plants.

Rackocy and colleagues from the University of the Virgin Islands Agricultural Experiment Station utilised deep-water raft hydroponics, similar to New Alchemy’s ‘solar pond’. The system was sophisticated, with filters, oxygenation systems, temperature and pH control systems, and their research focused primarily on the more technical aspects of aquaponics, from nutrient balance to system design (Rackocy 1999a, 1999b, 2007). Rackocy also worked with the commercial operation of Nelson and Pade Inc.[[2]](#endnote-2) to develop training and educational materials. Nelson and Pade market aquaponics systems and supplies, planning services, educational materials and training courses, primarily in the United States.

The growing popularity of aquaponics may be fuelled more by social and environmental benefits and the promotion of a sustainable lifestyle, than by cold economics. Indeed, there have been very few appraisals of the financial costs and benefits of commercial aquaponics. Possibly the first quality review, including analysis of over 250 commercial aquaponics operations, was carried out by Love et al.(2015). They comment that the growing demand for locally produced food sold directly to consumers, has helped to promote the commercialisation of aquaponics. However, the most successful operations are those that diversify their revenue streams beyond the sale of aquaponics production crops by selling non-food products (e.g. aquaponics systems and supplies), services and training courses. The last decade has seen a growing number of aquaponics training courses and education programmes, often provided by private companies but also by community interest groups and educational institutions. The commercial courses tend to be well marketed, utilise quite sophisticated systems such as those run by ‘Humble by Nature’, utilising a sophisticated ‘Passive Solar Greenhouse’ and by ‘Bioaqua farm’ in their commercial Aquaponics Farm[[3]](#endnote-3). These courses promote a resort ethos, providing meals using the produce from the farm and including a social calendar.

## ]ha[Education Using Aquaponics

]fl[Engagement with nature has benefits beyond the development of Science, Technology, Engineering and Mathematics (STEM) knowledge and skills, because understanding the financial, environmental and social benefits of local production of food and improved access to fresh fish and vegetables provides insight into environmental sciences, economics, marketing and nutrition. Furthermore, there are other less tangible benefits. Barton and Pretty (2010) investigated the impact of ‘nature’ on self-esteem and mood, and they were able to prove the positive influence of experiences of nature on such parameters. The extent of the influence was found to depend on participant age and the duration, intensity and location of the experience. A five-minute active experience of nature (compared to longer periods including 10–60 minutes, half- and full-day experiences) had the strongest effect on self-esteem and mood, and the most intense influence was seen in people under thirty years of age.

While there is little doubt of the value of education in rural environments, these opportunities can be costly in terms of both time and money. However, such experiences can be especially valuable in or close to cities, and can be provided at low cost. The ‘Green Classroom’ in the Botanical Garden of the University of Ulm is visited by about 2,500 school-age students a year. It uses exp**eriential** **learning** to expand students’ biological knowledge and develop positive attitudes towards animals and plants. Students who have visited the Green Classroom show a better understanding of biology and ecosystems than their peers (Drissner et al. 2011). Utilising the whole university campus to provide a botanical tour, Ratnayaka (2017) showed that the outdoor, hands-on, experiential learning (botanical tour) increased student satisfaction and motivation, leading to a deeper understanding of the subject compared to instruction-based learning in a classroom. Student perception and their results in graded exercises improved by around 10 percent using active-learning compared to traditional classroom plant-related laboratories (Ratnayaka, 2017).

Aquaponics provides an attractive educational tool. The systems contain plants, fish and bacteria; they are self-contained ecosystems and they allow teachers and students to explore a wide range of science, technology, engineering and mathematics topics (Schneller et al. 2015; Genello et al. 2015). Even in a classroom far from the countryside, students can engage with nature in a very hands-on way, caring for the plants and animals, performing water tests, feeding the fish, planting, tending and harvesting the plants.

## ]ha[**Education, Aquaponics and Urban Farming Projects in and around Liverpool**

## ]hb[*Farm Urban*

]fl[Farm Urban was founded by two bio-science graduates, Paul Myers and Jens Thomas, from the University of Liverpool. They set themselves a goal of using their biological background and their interest in growing and eating healthy food to find solutions to food security challenges by ‘linking leading scientific research with local food production’ and ‘developing and testing the most efficient ways to grow food in urban environments’. Early in their story, Farm Urban recognised that aquaponics and urban food production provide a very effective focal point for education and engagement programmes. So, by focusing on sustainable urban living for local communities and by engaging with schools, communities, hospitals and universities, they started to develop and promote education programmes to demonstrate how anyone can produce healthy food in a sustainable and cost-effective way. They also wanted to draw attention to the wider issues around food security. Collaborating with the University of Liverpool and the Liverpool Life Sciences University Technical College, they developed workshops, STEM clubs and enrichment activities focused on a Produce Pod – a ‘hacked’ aquaponics system so that the secondary school students’ STEM clubs, using the produce pods, can participate in collaborative research providing and using crowd-sourced data and participating in online forums[[4]](#endnote-4).

## ]hb[University of Liverpool Guild Farm

]fl[The University of Liverpool Guild of Students set up the ‘Green Guild’ to encourage students not just to think about, but to get involved in ‘green’ and ‘sustainable’ activities. The Green Guild organises student-led volunteering initiatives and social enterprise projects as well as finding funding for its own initiatives such as ‘Student switch off’ – a competition between university halls of residence to save water and energy and increase recycling. Green Schools, in collaboration with the University Widening Participation team, places volunteers in local schools to promote sustainability and enterprise skills. The Green Guild also purchased a rapid composter and processes all of the food preparation waste, including, for example, the grinds from the in-house coffee shop, to create compost for their own roof garden and for other projects. The Green Guild also set up a Social Enterprise Challenge which, together with a generous grant from the ‘Friends of the University of Liverpool’, funded Farm Urban to design and install an ‘urban farm’ on the roof of the Guild of Students’ Building to demonstrate aquaponics growing techniques in a ‘typical’ disused urban space. The farm is maintained by Farm Urban and a group of volunteers and is used for education and outreach events to engage with school students and other members of the local community.

## ]hb[Alder Hey Children’s Hospital

]fl[The Alder Hey Children’s Hospital has just been through a quarter of a billion pound redesign to create one of the most innovative and environmentally sustainable hospitals in the world. The young patients were involved in every step of the design process, creating a fun, child- and family-centred environment in an eco-friendly building that generates a portion of its own energy, has ‘green roofs’ planted to encourage biodiversity and part-indoor, part-outdoor ‘playdecks’ so that even sick children can benefit from the feel of being outside while being kept safe from the elements. Funded by a legacy from a local Liverpool resident, Farm Urban designed and installed three bespoke aquaponic systems on the playdecks. The water from Koi and goldfish in the fish tanks feeds plants and vegetables in racks above, which in turn clean and filter the water. These systems provide a focal point for patients, parents, staff and visitors who enjoy feeding the fish and learning about the mini-ecosystem. Furthermore, the herbs and salad are used in the children’s meals by hospital chefs so that they enrich the diet of the children and encourage them to think about the source of their food and the value of fresh, healthy vegetables in their diet. This project has featured heavily in the local and national media.[[5]](#endnote-5)

## ]hb[University Technical College, Liverpool (UTC)

]fl[The Liverpool UTC has academy status; it is a life sciences technical college in the so-called ‘creative quarter’ of Liverpool, ‘the Baltic Triangle’. Its students are aged 14–19 and are being taught in an innovative hands-on laboratory environment that encourages the early development of a wide range of professional skills and student-led critical learning. Farm Urban runs an aquaponics enrichment programme with UTC students each year, which has produced a DNA double-helix-inspired aquaponic system that is on prominent display in the college foyer[[6]](#endnote-6). Farm Urban is also installing a productive farm and laboratory in the college’s basement. Aquaponics has been used at the school to provide a hands-on laboratory for life sciences, engineering and design students and to promote a dialogue around issues of global food security and its potential solutions.

## ]hb[Ness Gardens

]fl[Situated on the Wirral Peninsula, the award-winning Ness Gardens is Liverpool University’s botanical garden and research facility. The gardens were created in 1898 by Arthur Kilpin Bulley from Liverpool[[7]](#endnote-7). Bulley funded plant-hunting expeditions to the Far East and established the Bees Seeds company, famous for its packets of cheap seeds, which were sold for decades in shops like Woolworths[[8]](#endnote-8). The gardens were donated to the University of Liverpool in 1948 by Bulley’s daughter to use for research and education. It is a key visitor attraction on the Wirral. The Ness visitor centre is powered by an array of solar panels, it is topped with a green roof, and much of the food sold there is grown on site. Farm Urban transformed an overgrown conservatory attached to the visitor centre into an engaging installation showcasing different aquaponic growing techniques to inspire visitors.

## ]hb[Duke of York Young Enterprise Award

]fl[Farm Urban was awarded a prestigious Duke of York Young Enterprise Award in 2016. After reaching the final, the managing director, Paul Meyers, had to deliver a one-minute ‘elevator pitch’ to explain what Farm Urban is, who is involved and what they do. The award was a validation for their business approach, which is more about slow, organic growth while also developing skills and a network of collaborators, rather than seeking large amounts of capital investment.

]ha[**Conclusion**

]fl[Urban farming is unlikely to replace conventional agriculture; for example, it makes little sense to grow easily transportable foods like potatoes in cities. However, it should be complementary to it, growing, for example, high-demand, easily perishable, short shelf-life foods, which are consequently the foods that are highest on the charts of food that is wasted, such as salads. The first step is to educate the public in the benefits of healthy eating and local food production.

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