

Homegreens: Aquaponics and Education

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Abstract

The Homegreens project aims to develop small freshwater or saltwater aquaponic systems, which can be installed in schools, serving as a pedagogical tool for the apprenticeship of subjects such as biology and sustainability to the juvenile audience. A multidisciplinary team of designers, biologists, and agronomists was responsible for the project's research. The development and installation of experimental models, for qualitative analysis of user interaction, determined the methodology layout.

This small-scale aquaponic system consists of two different grow beds, an aquarium with a capacity of 45L, a separating barrier for plants' roots, a biofilter mesh with an integrated aerator, a valve for sediment cleaning, and two tripods.

The involvement and the interaction with the Homegreens' aquaponic system provides a group learning opportunity, which contributes to environmental literacy in children with relevant values and experiences.

Keywords: Aquaponics, Education, Ecosystem, Sustainability, Design.

Introduction

Education and pedagogical strategies for sustainability

By 2050, the world population is expected to reach 9 billion people (Touliatos, Dodd & McAinsh, 2016; FAO, 2018). In addition to this fact the emancipation of developing countries, reducing the disparity between them and developed countries, constitutes a threat to the current management of environmental resources (FAO, 2018) and contributes to environmental degradation.

Assuming the urgent need to face the challenge of leaving a more sustainable and safer planet as a legacy for future generations and recognizing that education is a priority since it has a catalytic effect on society promoting values, attitudes, capacities, and behaviors, the United Nations declared the decade 2005-2010 as the "Decade of Education for Sustainable Development" (UNESCO, 2005). However, to foster environmental ethics in children is necessary to create pedagogical methodologies aiming to obtain greater efficiency in the teaching/learning process.

Pedagogical methodologies such as Project-Based Learning or PBL (Bell, 2010) present a viable alternative to traditional methodologies. PBL was inspired by the ideologies of John Dewey, a pedagogue and reference philosopher of the progressive school's movement, supported by principles that aim to provide children a learning experience based on practical activities. For Dewey, the application of these methodologies not only makes children more aware of the world, preparing them for the future but also provides them with a deeper understanding of contents (Dewey, 1986). This allows children to take advantage of their natural curiosity to explore subjects according to their interests, allowing them to remain motivated and receptive to the contents of several knowledge areas, such as mathematics, physics, biology, among others (Claussen, 2017; Blumenfeld et al., 1991).

The cognitive stimulus from these didactics contemplates the development of young thinkers, who learn to organize research and apply strategies, preparing them to identify and face real-world problems, which are constantly changing (Bell, 2010). Richard Louv also mentions John Dewey in his work – "Last Child in the

Woods”, as an important reference in the implementation of educational practices that promote student interaction with local ecosystems, outside the school perimeter. These activities are at the basis of environmental education principles, to which Louv draws a parallel with experimental education. In this way, the author defends the reformulation of traditional teaching through the introduction of new teaching practices that encourage children's relationship with nature and its phenomena as an essential part, not only of learning but also of their physical and emotional health balance (Louv, 2008).

Given these changes the classroom space is recognized as a potential space for intervention, where design plays an important role in the development of objects/systems, supporting different pedagogical strategies. Through this process, it is possible to analyze, identify and create tools that provide children with experiences capable of making them more aware of environmental literacy, citizenship, and social-cultural skills, among others, whose role will be fundamental in their lives.

Aquaponics as an educational tool towards environmental literacy

Aquaponics is considered an exemplary activity to achieve sustainability and its dissemination is regarded as fundamental for global awareness about the preservation of nature and its resources. The growing interest in this activity, especially within the humanitarian sphere, has encouraged research around the world (Somerville et al., 2016), to design increasingly efficient systems and achieve the sustainability goals defined by the United Nations until 2030 (UNESCO, 2017).

This is a technique considered more efficient compared to other models of food production, as it allows the simultaneous production of fish and horticultural species through the same water circuit. Aquaponics is essentially the combination of hydroponics and aquaculture (Blidariu & Grozea, 2011): hydroponics is a technique that enables the farming of soilless plants, using a variety of inert grow beds that support their development, while being irrigated with a nutrient solution providing their growth; on the other hand, aquaculture consists in the production of fish or other aquatic animals, in an isolated and controlled environment (Jensen, 1997; Blidariu & Grozea, 2011; Somerville et al., 2016). The main advantage of this farming technique is the highly efficient management of water resources, notably through the permanent recycling of water, in which the waste metabolized by fish provides a benefit to the growth of plants (Graber & Junge, 2008). It is possible to consider aquaponics as a simulation of an ecosystem easily found in rivers, which is sustained by a set of interactions among members of a specific biotic community, particularly fish species, vegetables, and nitrifying bacteria, which inhabit equipment designed according to certain specifications.

The nitrogen cycle is the main biological process responsible for triggering the actions that take place in aquaponic systems. Thus, it's the process of nitrification that transforms the waste produced by fish into food for the plants. To make this possible, the water is mechanically filtered to release the solid particles metabolized by fish, passing through a support structure of nitrifying bacteria, called a biofilter, where the ammonia is transformed into nitrites. Subsequently, these turn into nitrates, which are absorbed by plants. Going through these steps, water recirculates to the fish tank completely purified (Somerville et al., 2014; Blidariu & Grozea 2011).

This way, the use of this ecosystem in indoor spaces can be an important way to communicate concepts related to the environment and sustainability to children. While observing a set of biological phenomena, children participate in its maintenance through hands-on activities. It allows them to conduct experiences intended to contribute to their awareness about environmental literacy, which involves nature's organisms and resources, leading to a systemic understanding of the world: “Environmental literacy (...) is essentially the degree of our capacity to perceive and interpret the relative health of environmental systems and to take appropriate action to maintain, restore, or improve the health of those systems” (Roth, 1992, P14). According to Vitor Papanek: “(...) the human being shapes society and its future through what is taught to young people” (Papanek, 1995, p.235), so the dissemination of these contents is considered relevant because it contributes to the sedimentation of a chain of values, on which children establish a cosmovision.

Methodology

The Homegreens' aquaponic system concept was created as a pedagogical tool to promote the infant-juvenile user's learning experience and to ensure the biota's development necessary conditions. The design process of this small-scaled domestic aquaponic system was developed in five stages. The first one was the gathering of information about aquaponic farming, in which food production systems were analyzed and researched. In the second stage, users were involved in the product design process according to the principles presented in IDEO's methodologies (2015). A probe system was implemented during a year in a 1st-grade school (EB1/JI do Carvalho, Alcobaça, Portugal, with students between seven and ten years old), which was chosen due to its contemporary pedagogical practices, combining Project-Based Learning and traditional teaching (figure 1). The rele-

vant data on the interaction between children and the probe system was later incorporated into the experimental models. The third stage consisted in the construction of experimental models to validate formal-functional solutions. The fourth stage focused on defining materials and production processes for the system components, and prototyping. Finally, the fifth stage consisted in installing the Homegreens' aquaponic system at the same school and collecting data through interviews, with both teacher and children, leading to a qualitative analysis regarding its performance.



Figure 1

Homegreens Aquaponic System

The aquaponic system final design aims to facilitate the user's daily tasks, and the understanding of the ecosystems' biological processes, as a way to promote environmental literacy in children, awakening them to sustainability and other related themes.

With the implementation of the probe system at the EB1/JI do Carvalho, it was possible to establish a set of important guidelines for the system's design, such as: simplifying its components (allowing children to operate the system easily and intuitively); creating a design capable of promoting interaction between children and living organisms (like plants, fishes and bacteria); selecting materials which make it possible to display the biological phenomena responsible for the ecosystem's activity, and developing a system in a scale capable of promoting group learning activities.

This way, the Homegreens aquaponic system includes two grow-beds, one biofilter mesh with an air diffuser, one root separator barrier, one aquarium, one valve for sediment extraction, two tripods, and one bracket to install the air pump (figure 2):

- the grow beds were developed using the raft technique, allowing them to be placed, with the plants, directly on the water. Two distinct configurations were developed, one placing plants in hydroponic pots and the other placing plant along with longitudinal slots. The grow beds (which allow access to the aquarium) were made of composite cork, a waterproof comfortable to the touch material, which was important due to the context of its use;

- the biofilter mesh with an air diffuser, is designed to facilitate the device's assembly and cleaning by children. This component was also designed to communicate the presence of bacteria to children, through color changes during its use. It provides a surface for the fixation of nitrifying bacteria and is also responsible for the air's circulation throughout the ecosystem. It was produced in white PLA (Polylactic acid) filament through an additive process;

- the root separating barrier divides the aquarium space between fish and the plant's roots, establishing a balance. It was produced in Polymethylmethacrylate, better known as transparent acrylic, which allows users to visualize the growth of the roots;

- the aquarium was produced in a semispherical format, with the capacity of 45 litres, allowing children to gather around it, and making it easier to filter the solid waste produced by fish, which clusters at the bottom. This component is also made of transparent acrylic made exposing all biological phenomena.

- the sediment extraction valve consists of a device installed at the bottom of the aquarium, which extracts the solid waste produced by fish. It's composed of a handle, designed to adapt to the children's hands, two elements fixing it to the aquarium, and a spring-loaded mechanism. This was produced in nylon and carbon fiber filament, through an additive manufacturing process;

- the tripods, designed with different heights and produced in black lacquered steel, were created to

make assembly and transportation easy, allowing an effortless implementation in different schools;
- the air pump fits a bracket attached to one of the legs of the aquaponic system, made in nylon and carbon filament.



Figure 2

Results

Implementation in the school context

Once installed at the EB1/JI do Carvalhal in Aljubarrota, the Homegreens' aquaponic system was overseen by the 4th year class (with children aged between nine and ten), which had already cared for the probe system (figure 3). The teacher Paula Almeida was responsible for monitoring the process in both phases.



Figure 3

During this activity, a group of plants, fish, and a set of tools were selected, to help gather data. Plants were selected for the children's familiarity with them. The chosen fish species was the Garra Rufa, due to their natural curiosity, which allowed children's physical interaction. Children conducted lab experiments to evaluate the water's ammonia and used a smartphone app to obtain extra information about the water's quality. A notebook was also developed to collect the results and help children during the ecosystem's maintenance activities.

The implementation of the aquaponic system started on the 24th January 2020, and ended on the 13th March 2020, due to the COVID-19 lockdown, which led to the closing of schools. In this sense, the collection of results was partially compromised since the activity period of the aquaponic system was considered insufficient. To collect data, two interviews were carried out by videoconference, one with teacher Paula Almeida¹, and another with the students² (figure 4).

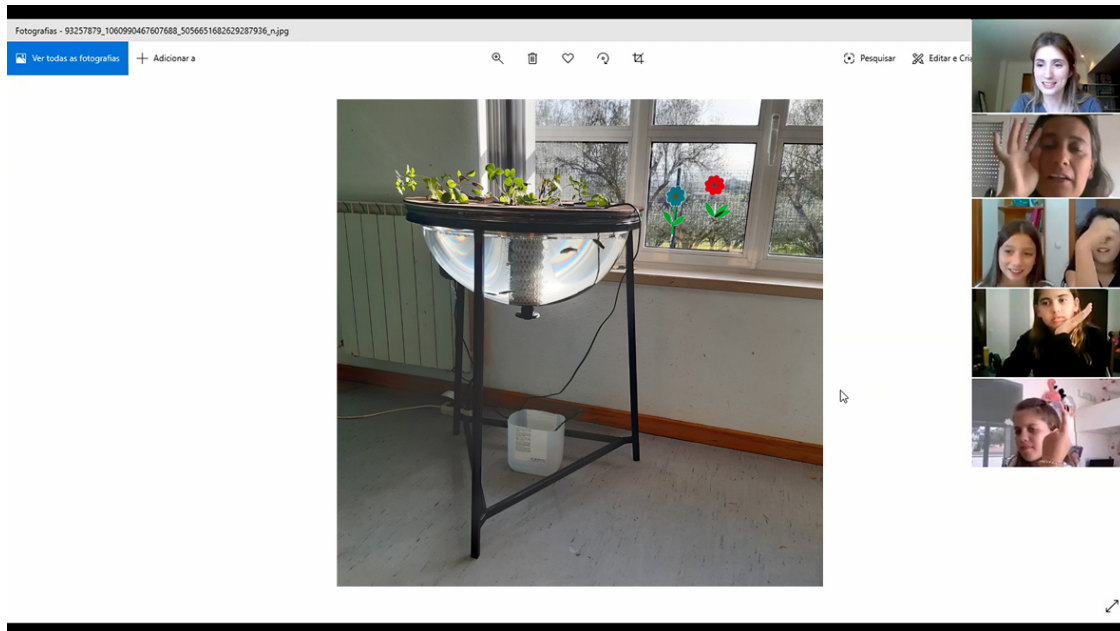


Figure 4

Through the systems' implementation, it was possible to validate the correct functioning of the aquaponic system, although formal adjustments are still needed to optimize some of the components, improving the user experience. During the interviews, the teacher Paula Almeida recognized the potential of this experience in contributing to the development of children's skills. She said that "(...) at the level of citizenship, respect for the ecosystem, it has many benefits because they (the children) knew that the plants were only well, if the fish were also well, so it is all about symbiosis, which they are part of it". It was also mentioned by one of the children that these activities are important due to the responsibility that is instilled in them: "it is more of a responsibility to have, and the children must have responsibilities to learn, which will come in handy later on". Regarding the importance of using this kind of tools in the educational context, the teacher recognizes that these activities have a positive impact on children's learning, allowing them to remain motivated and receptive, claiming that up to the 6th grade, practical contents are easily learned, while in lectures they listen for 5 min/10 min and then get distracted.

To realize the ecosystem maintenance tasks, the class was divided into four groups, each one responsible for the system for one week. The tasks were planned and divided among the children, and as mentioned by the teacher, the groups that had the opportunity to repeat the experience for the second time were already able to carry out maintenance practically autonomously. During the interviews, several children highlighted proximity and play episodes that arose from their interaction with the fish, which became possible due to the design of the system and the species' selection: "I really liked when, in the upper part of the aquarium, in that part of the cork, there was an opening for us to give food, we put our hands there and they came to us and always moved from one side to the other (...) I liked to play with them". The size of the system was also mentioned by the children as a factor of enthusiasm.

At the end of the activity, it was possible to notice that the children were sensitive to imbalances in the ecosystem, always seeking to ensure its well-being. When the students were asked about what they liked least about the experience, one of them mentioned "the color becoming darker", referring to the ammonia test, which represented a water quality imbalance. It is also noteworthy that at the end of the experiment, the children already used some technical concepts to refer to physicochemical indicators of the water's evaluation in the ecosystem, like pH, ammonia, among others, as teacher Paula said: "some of them already know how to distinguish NO₃ from NO₂. The most attentive were already able to use certain terms such as pH or CO₂".

This activity showed the interest and motivation of the children to participate throughout the entire

¹ Link to interview with the teacher Paula Almeida: https://www.youtube.com/watch?v=_Rvks2M4O20

² Link to interview with the students: https://www.youtube.com/watch?v=frl4_ZbYku0

experience, from the implementation phase to the process of collecting results. When the teacher was asked about what remained of the experience, she mentioned: "Everyone said they felt like authentic scientists. The motivation was two hundred percent. No one ever forgot to take care of the fish and measure the water levels."

Conclusion

In conclusion, the performance of tasks by the children allowed them to assimilate and understand some important biological concepts and phenomena. Maintenance activities, such as feeding, cleaning, annotating, and interpreting the water quality measurements, provided the understanding of the ecosystem's health, also highlighting the importance of the children's participation in this biota's survival. The pedagogical potential of the inclusion of this tool in the school, and the relevance of the children's involvement in multisensory experiences aimed at maintaining a real ecosystem promotes learning about its balance and functioning. This strategy was important in stimulating insights in children's and preteen's, not only about environmental literacy but also their sense of responsibility. It creates the ecological notion of belonging to a symbiotic cycle and the consequence of their actions in the ecosystem while generating knowledge about a food production practice. In this way, this research project opens paths for future investigations, which will allow not only to evaluate and improve the performance of this aquaponic system but also to eventually scale it into new contexts and provide new and different solutions.

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