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Blue-Green Farms of the Future: Using Aquaponics at Primary School to Foster Sustainable Development.

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Table of Contents

Abstract:

Introduction: The United Nations has projected an increase in global human population by more than one billion people, reaching 8.5 billion in 2030. A large number of those people (66%) are predicted to live in cities by the year 2050 (UN, 2015). This raises questions on how the present and future challenges of sustainable food provision ought to be addressed. AGENDA 21, is an action plan that encourages and calls for public participation and active involvement of non-governmental organizations and other groups towards the realization of its goals in promoting sustainable agriculture, transfer of environmentally sound technology, science for sustainable development and promoting education (Anon, 1992). Within this context, educational institutions such as primary schools can be considered as important platforms, from where some of the objectives in Agenda 21 can be realized. We acknowledge that education is a critical component, for promoting sustainable development and improving people's capacity to address environmental and development issues.

Aim: The aim of the research was to assess potentials for aquaponics system implementation as a tool for enhancing food literacy to promote SD among children at Primary schools in Denmark. The main motivation behind the study was to gain insight into the prospects for incorporating the new technology into the educational system, and any other potentials that would increase knowledge in food literacy among the pupils.

Methodology: Action research approach was applied in the search to find answers to our research problem. A participatory component of the study was achieved by conceptualizing and building an innovative aquaponics system. It was set up at one of the public primary schools in Copenhagen, as an intervention to better understand our research problem while giving the system users a continual opportunity to use it, evaluate and improve it into the future. Qualitative methods in form of semi-structured interviews was the main method applied to answer the research question complemented with observations. A total of six face to face interviews were carried out: A convenience sample of four teachers was recruited from the school including the headmaster, one technical bio farmer representing a community, and a group of four students from the class that was introduced to aquaponics. The methodology of text analysis is build according to the thematic analysis of the interviews based upon the theories of Kvale's (1997, 2007) and that of Braun and Clarke (2006).

Results: The analyzed text was initially divided into seven different "codes" under the names: challenges, opportunities, relevance, expectations, senses, stakeholders and sustainability. These subsequently formed diverse themes that summarize and give meaning to our data. The key ideas expressed in each theme underline the consistencies, differences as well as any contradictions that might have occurred. Connections between different themes in the process of explaining our findings to establish coherency was achieved.

Conclusions: The technology is seemingly complicated, but it could be possibly applied in the primary school settings and used as a learning tool in a range of different subjects. It is central for the initiative takers to understand complexities of the technology and objectively estimate the available resources at their disposal. Some patterns that could hinder aquaponics implementation include; inadequate commitment of the system users, poor communication among stakeholders and insufficient engagement and dedication. To fully conclude on the successful implementation of using aquaponics at schools, more research is needed especially on evaluating the efficacy of aquaponics on improving food literacy.

Keywords; Aquaponics, Sustainable Development, Action Research, Children's Food Literacy.

1. Introduction.

Sustainability, environmental ethics and responsible use of earth resources continue to attract attention all over the world as human population grows with rapid urbanization taking place. As recent as 2015, the United Nations (UN) projected that the world population will increase by more than one billion people within the next 15 years, reaching 8.5 billion in 2030 and a greater majority of those people (66%) are predicted to live in cities by the year 2050 (UN, 2015). When viewed from the perspective of food systems in our contemporary society, the current evidence available on a worldwide unsustainable system cannot be ignored, which raises questions on how the present and future challenges ought to be addressed (FAO, 2010; UNDP, 2016). The sustainability concept remains relevant today as it was in the past, when its economic, environmental and social pillars were collectively revisited, under the United Nations Conference on Environment & Development held at Rio de Janerio, Brazil, in 1992. A product from the summit termed AGENDA 21, is an action plan whose successful implementation was mostly pegged on various governments around the world. The agenda however, encourages and calls for public participation and active involvement of non-governmental organizations and other groups towards the realization of its goals. Some of the worthy ideals set out in the various sections of the Agenda included: Promoting sustainable agriculture, transfer of environmentally sound technology, science for sustainable development and promoting education (Anon, 1992).

On following Agenda 21, calls for sustainable food & farming methods have continued to intensify all over the world with international organizations such as the United Nations-Food and Agriculture Organization focusing greatly in areas such as those dealing with sustainable diets. A good example is the International Scientific Symposium "Biodiversity and Sustainable Diets: United Against Hunger" which was organized in Rome in the year 2010 jointly by FAO and Bioversity International; it was aimed at addressing the linkages among agriculture, biodiversity, nutrition, food production, food consumption and the environment. The result of which was a report with recommendations on how the concept of sustainable diets could be promoted and applied in different agro-ecological zones (Burlingame and Dernini, 2012). There has also been a surge in the blue and green trends globally contributing towards Sustainable Development (SD). In the United States for example, there exists a Recirculating Farms Coalition

(RFC) which is a nationally focused, non-profit collaborative group of farmers, educators, organizations and many others committed to building local sources of healthy, accessible food. The coalition uses research, education and advocacy, working together to support development of eco-efficient farms that use clean recycled water without soil as the basis to grow food (Anon, 2013). Similar approaches and studies are taking place in other parts of the world too. In the year 2010, Rahman, Barmon and Ahmed, in Bangladesh, evaluated the performance of a unique system called 'Gher' farming; a technique incorporating joint operations of three integrated enterprises: freshwater prawn, fish and High Yielding Variety (HYV) rice. One of their findings was that investment in education and creation of a hired labour market for females would improve technical efficiency (Rahman, Barmon and Ahmed, 2011). The need for education for sustainability is being championed by the United Nations Educational Scientific and Cultural Organization (UNESCO), consequently sparking scholars, researchers and educators alike to look into new and old improved ways of creating and sharing knowledge through learning institutions (Anon, 2002). These concepts have further resulted into the emergency of new interests in teaching principles such as the experimental science approach: The Science Technology Engineering and Mathematics (STEM). Mr. Vaugh, a biology teacher in Hawaii is a good example of individual teachers who have taken action in this direction by starting a project to use aquaponics (AP) as a STEM tool to engage his students who seemed to want a deeper and more relevant education. He saw the AP system as one that will allow a whole host of relevant lessons that are not only cross disciplinary, but highly engaging; envisioning the AP system as a platform for forming, testing, and revising scientific ideas and a pathway towards the mastery of the scientific method (Vaughs, 2014).

Within this context, educational institutions such as primary schools can be considered as important platforms, from where some of the objectives in Agenda 21 can be realized. While acknowledging that education is a critical component, for promoting sustainable development and improving people's capacity to address environmental and development issues; we fully support the view that enabling school children to be literate about food in areas such as: how food is produced; with some hands-on socio-cultural and technical activities, basic concepts on sustainability, environmental and ecological responsibility, nutrition and health implications etc. should be at the center of addressing some of the challenges of today's food world. However, insufficient information is available from a Danish perspective on the involvement of young children in technological approaches such as aquaponics, to food production that would enhance their food literacy. Food literacy in this context encompasses proficiency in food related skills and knowledge; this involves understanding of:

- where food comes from
- The impacts of food on health, the environment and the economy; and
- how to grow, prepare, and prefer healthy, safe and nutritious food. (Truman, Lane and Elliot, 2017; Ontario and Network, 2014).

Schools, together with the local communities and families should be engaged in collective action towards food education. Conflicting values and arguments on food production between global free market and local production persist, however, the need for sustainable diets is now being addressed by new trends of farming. These can be seen in municipal (cities and urban) spaces by use of techniques such as (rooftop) urban gardening. Aquaponics, which is the basically a combination of aquaculture (raising fish) and hydroponics (the soil-less growing of plants) in one integrated system can be considered as one of the smart food production approaches that holds potential, not only in addressing some of the food system challenges in society; but by its very technical nature, being used as an educational tool in schools. Aquaponics can be integrated as part of the educational curriculum in order to raise awareness about the critical importance of food education in Danish schools.

This project work was grounded in science and technology, through an action research strategy. We sought to reap some benefits in simplicity by replicating a natural ecosystem in food production by implementing an aquaponics system at a primary school in Copenhagen, Denmark. It was accomplished in collaboration with other project participants that we identified and teamed up with for the project. As researchers, we were inspired by Kurt Lewin’s approach to carrying out research that will eventually help a practitioner. In his paper entitled "Action Research and Minority Problems", Lewin (1946) identified two key factors namely: a great amount of goodwill-that is, the readiness to face the problem, and then to do something about it-through organized and efficient action. We embarked on a scientific fact finding mission, employing basic qualitative research methods such as interviews and observations, along with the experimental design and setup of the aquaponics system as a technique expecting to bringing about some long-term positive change among the users. Martyn Denscombe (2010) in his book “small-scale social research projects” expressed that, the purpose of research for an action research strategy is to solve a particular problem and to produce some guidelines for best practice. We acted on the basis that a ‘hands-on’, small-scale aquaponics system implemented at one of Denmark’s primary schools, would contribute as part of a solution to practical educational and societal needs that touch on the food system. Subsequent guidelines for practice will be featured in the form of recommendations and as a part of our discussions as presented in this thesis. The research problem we identified lies within the contemporary approach to teaching, at primary level in Denmark focusing on food production. We settled on a reflective action based process of progressive problem solving, taking the lead among "our community of practice" while staying on course in order to answer our research question. It can therefore be said, that we carried out a participatory type of action research.

This thesis unfolds in 9 sections in the following manner: Section 2. presents the scope of our research area as outlined under delimitation. We proceed to ask our research question that we hope is answered following the subsequent sections that ultimately address our research problem. Section 3. takes us through a detailed understanding of aquaponics from its definitions, core components, the different types of systems and briefly on what is known currently known in the technology. Section 4. features the state of the art in which present a wider view of the global challenges relating to food production, the various approaches that seek to address the concept of sustainability and aquaponics as it has been featured in relation to education. It is in this section that we identify a gap and niche for this research work. In Section 5. we present a methodological approach applied in the study. In Section 6. we examine the theoretical framework by featuring five theories that form the basis for a synergistic, educational theoretical background. We explore the concepts and models while keeping a focus in a way that preserves their fit and relation to education and aquaponics. In Section 7. We present results and analysis of the qualitative interview data. Section 8. It is a general discussion linking our findings to other relevant literature.

2. Delimitation.

Our research problem potentially touches on various issues that would be extrapolated to individual research questions. However, we transformed it into one specific question encompassing those aspects we sought to answer. In so doing, we automatically delimited our focus to include only those elements featured in the research question. The focus areas were:

1. The promotion of food literacy and social interaction.
2. The budget (cost) for a fully-operational unit of aquaponics
3. The development (design considerations) and testing of the unit.
4. The demonstration and evaluation for teaching at school.

The vision for the study is wide and would include areas such as: investigating acceptance of aquaponics produce, studying attitudes of practitioners and users of the system, testing multiple systems with varied inputs to evaluate economical sense of aquaponics production, experimenting alternative feeds sources to address challenges on fish feed and many other areas warranting attention. However, we acknowledge some resource limitations such as: inadequate funds to execute them, time requirements it would take to completion, access to and assurance of commitment from project participants, depending on the scope. We therefore, deliberately chose to work on the areas featured in our research question with the knowledge that they would be sufficient in answering our problem. Having formulated our research question, we structured our study in a way that would enable us find satisfactory answers. These considerations informed our choice for the research strategy, the methods and theories that we used as they are presented in this thesis.

2.1. From research problem to research question.

Practical aquaponics promises to deliver a hands on problem based inductive learning tool for education. To this end, we were faced with the challenge of taking action. After mapping out the situation, a single case featuring one of Denmark's public primary schools in Copenhagen seemed feasible for intervention. Practical incorporation of an actual aquaponics system was to be an integral part of the study, in addition to qualitative methods for diagnosing the problem. These challenges led us to the research question:

How can a low cost full-operational model of aquaponics be developed, tested and used for teaching in the promotion of food literacy in Danish Schools?

To answer the research question, we sampled a project team, designed and developed a low cost aquaponics system and set it up at the school for the educators and pupils to use in teaching SD concepts and some elements of STEM. The specific objectives of our study were:

1. To make it feasible for teachers to incorporate it into the existing curriculum.
2. To create learning insights for the school children through experience, facilitate their full appreciation of the senses and foster their social interactions.
3. To make it possible for collection of data, such as water quality measurements, establish feed ratios for further learning and future improvements of the system.

2.2. Aim of the thesis.

The main aim of the thesis was to assess possible theoretical and practical opportunities and challenges among other understandings, for implementing an aquaponics system as a tool for enhancing food literacy to foster SD among young people at Primary schools in the Danish context. The opportunities for incorporating the new technology into the educational system, and any other potentials that would increase knowledge in food literacy among the pupils was the main motivation behind the study. Empirical data was collected by means of qualitative interviews from: an aquaponics technical expert, teachers who showed interest in using the tool in the education and some pupils. Based on the initial conversations with the people involved, we noted a positive attitude especially from the educators towards aquaponics, and the idea of setting it up in a school was well received. However, we were also aware of the time, financial and some other resource constraints, the primary education institution would have to face in Denmark, but we sought to confirm and investigate this further. Our expectations being: findings from this project work, could be used as inspiration or guidelines for other teachers and schools willing to take advantage of aquaponics. It could also be an incentive for further research in the subject matter.

2.3. List of abbreviation and key concepts.

ABC-Australian Broadcasting Corporation
AP-Aquaponics
AOB-Ammonia-Oxidizing Bacteria
DWC-Deep Water Culture
EBLS-Experience Based Learning System
EIT- European Institute of Innovation and Technology
ELT- Experiential Learning Theory
FAO-Food and Agriculture Organization
GMO- Genetically Modified Organisms
IFS-Integrated Food Studies
KT- Knowledge Triangle
NOB- Nitrite-Oxidizing Bacteria
NFT-Nutrient Film Technique
OECD-Organization for Economic Co-operation and Development
PBL-Problem Based Learning
RAS-Recirculating Aquaculture System
STEM-Science, Technology, Engineering, Mathematics.
SD-Sustainable Development
UN- United Nations
UNDP-United Nations Development Programme
UNESCO-United Nations Educational Scientific and Cultural Organization
ZPD-Zone of Proximal Development

3. What is aquaponics.

There have been several attempts to define aquaponics and all come down to the essential understanding of aquaponics as an efficient bio-integrated food production system of two mature food production disciplines: aquaculture and hydroponics. One of the most detailed definitions that we came across tends to explain the integration from the system constituent parts with some examples and details of its working principles:

"Aquaponics may be defined as an integrated quasi closed-loop multi-trophic food production system comprising a recirculating aquaculture system (RAS) and a hydroponic unit" (Goddek et al, 2016)

The plants and fish are cultured together in a mutually beneficial series. Waste produced by the fish contains lots of beneficial nutrient sources (e.g. phosphorus and ammonia) which is harmful to the fish if they remain in water in great quantities. However, these "wastes" through the action of nitrifying microbes (e.g. the genus *Nitrosomonas* and *nitrobacter*) make good liquid fertilizer constituents that are taken-up by the plants, in the process purifying the water (Graber & Junge, 2009; Goddek et al., 2016a; Gunning, Maguire, and Burnell, 2016; Love et al., 2014; Buzby & Lin, 2014).

The UN-FAO, defines aquaculture as: "the farming of aquatic organisms, including fish, mollusks, crustaceans, and aquatic plants. Farming here implies some form of intervention either by individuals or corporate ownership of the stock being cultivated in the rearing process to enhance production, such as regular stocking, feeding, and protection from predators (Parker, 2012). Hydroponics on the other hand is defined as the cultivation of plants in a soilless medium (FAO, 2016a). While aquaculture is contributing to solve food security concerns, it cannot solely be achieved by simple mass production. Several problems mostly of the environmental type are known to arise from aquaculture, these include: farm discharge pollution that leads to eutrophication, habitat modification and chemical pollution from antibiotics and pesticides and the depletion of fish due to fishing to provide fish feed ingredients (Somerville et al, 2014). These concerns imply that aquaculture ought to be practiced in conjunction with sound environmental and fisheries policies to ensure a productive and sustainable system, something which has not been significantly achieved to this date. There are also problems associated with hydroponics when practiced as a standalone method using chemical nutrient solutions. These include: chemical interactions in the nutrient solutions; certain elements are capable of bonding in solution and therefore altering their formulation making their availability unpredictable. Unlike a natural ecosystem, such as the one mimicked by aquaponics, where nutrients are availed in a form easily taken up by plant roots; as a function of pH of the nutrient solution, a dynamic equilibrium between dissociation, complexation, and precipitation reactions distributes ions over different soluble complexes and precipitates (De Rijick and Schrevens, 1999). All these changes can alter the way in which plant roots react to the nutrient solution in hydroponics. For example, it has been reported that phosphate, with three oxidative states, is capable of bonding to iron and manganese depending on solution pH (Thomas and Paparozzi, 2013 c.f De Rijick and Schrevens, 1999). Such reactions may affect their bioavailability to the plants leading to deficiencies. The reliance on chemical formulations, which is dependent on mining resources that are exhaustible; that further depend on the fossil fuels industry; ends up in a cycle that is not sustainable, besides harming the environment. Furthermore, spent chemical solutions have to be dumped at some point as the nutrient level drops and complexes become toxic, all of which is detrimental to the environment.

In a standard recirculating aquaculture system (RAS), the organic matter ("waste") that builds up in the water is filtered and removed so that the water is cleaned for the fish but in an aquaponics unit, the nutrient rich effluent from the fish tank is filtered through an inert substrate in the hydroponic bed containing plants that help function as a bio-filter by stripping off ammonia, nitrates, nitrites, and phosphorus so that freshly cleansed water can be recirculated back into the fish tanks (Parker, 2012). Nitrifying bacteria inhabiting the grow media play a critical role without which the whole system collapses. The genus *Nitrosomonas* that are Ammonia-oxidizing bacteria (AOB) consumes ammonia (NH3) and convert it to nitrite (NO2-) and the genus *Nitrobacter*; Nitrite-oxidizing bacteria (NOB) consume nitrite (NO2-) and convert it into nitrate (NO3-) which the plants use to grow. The bacteria therefore help in nutrient cycling, by metabolizing the fish waste and the process is called nitrification. The hydroponically grown plants assimilate the resulting nutrients as liquid fertilizer. Figure 1, shows an illustration of a simple aquaponics system. The output from the system are products such as fish, fruits and vegetables together with reductions in nutrient pollution into watersheds (FAO, 2016).

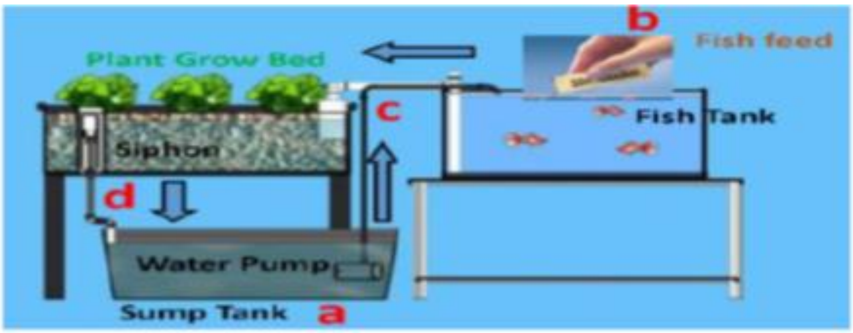


Figure 1. A design illustration of a simple aquaponics system in which: a) water pump in the sump tank facilitates water recirculation as it collects from the grow bed, pumping it into the fish tank while it becomes simultaneously aerated. b) The fish are fed appropriately and adequately. c) Effluent from the fish tank is channeled back to the grow bed through an overflow mechanism while maintaining a constant height in the fish tank. The grow beds contain inert grow media that supports the plants and act as a mechanical filter; nitrifying bacteria and preferably some earthworms in the media aid in the conversion of dissolved "waste" and the breakdown of solids. The end result are nutrients that become assimilated by the plants for growth and development. d) Resulting clean water falls back into the sump tank through an auto siphon mechanism to be continuously recirculated in the closed loop.

In aquaponics, plant growing units are the determinants in identifying or naming the types of aquaponics system built. Currently, there are three main types known, namely: the media bed method, also termed as particulate bed; the nutrient film technique (NFT) method; and the deep water culture (DWC) method; which is also called the raft method or floating system. The technical details of each type of aquaponics system are beyond the scope of this work. However, having decided to work on the media bed method for this research, after deliberating on the technical level and input requirements; it is important to note some basic specifications that constitute a media bed system of aquaponics: Besides the fish tank and the water/air pumps that are essential components for all aquaponics units; the media beds must:

A. be made of a strong inert material.
B. have a depth of about 30 cm.
C. be filled with media containing a high surface area.
D. provide adequate mechanical and biological filtration.
E. provide separate zones for different organisms to grow and

F. be sufficiently wetted through flooding and draining or other irrigation techniques to ensure good filtration. (Somerville et al, 2014)

Aquaponics continue to be popularized as having potential to support economic development, enhance food security and nutrition through its efficient resource usage. It has been touted to give higher yields for vegetables, fruits and fish with a reduced need for resources such as labor and land while optimizing the utility for water through recirculation (FAO, 2016). Being a controlled system, aquaponics combines a high level of biosecurity with a low risk of disease and external contamination. The need for using fertilizers and pesticides commonly applied in conventional food production is not necessary. These positive aspects make aquaponics a potentially useful tool in overcoming some of the challenges of traditional agriculture, that are associated with freshwater shortages, climate change and soil degradation (Somerville et al, 2014; FAO, 2016).

Aquaponics is now considered as one of the "blue growth" approaches. A climate-resilient system, that focuses on improving productivity and performance because it offers opportunities for innovation, and for production in environments where agriculture would not be traditionally possible (FAO, 2017). It can therefore be recommended as the method of choice for places with poor soils, places where water and land for cultivation are scarce such as in: urban areas, arid climates and low-lying islands (FAO, 2016a). However, it is important to note that, besides the many advantages that comes with aquaponics; there is a combined risk of failure due closed loop systems dependencies: for example, a collapse in aquaculture is likely to be transferred to hydroponics and vice versa. To mitigate such risks, more research is needed, like the one carried out recently by Goddek and colleagues in 2016, to delink the two systems, in what is now referred to as decoupling among the aquaponics scientific community (Goddek et al, 2016a). Expert assessment and occasional consultation is therefore needed for successful implementation.

4. State of the art.

4.1. Literature systematic review.

For our methodology in doing the state-of-the-art, we first created a system for registering, analyzing and summarizing the literature in Google drive. By creating a shared link with folders into which we ordered several documents; we were able to label them according to subsections touching on the areas that we considered relevant to the whole project. These included theoretical background folders, with a collection of publications from journal articles, reviews, newspaper articles, conference proceedings, technical reports, digital books, our own previous study project and course lectures and some webpage links. We also created folders for summary texts of our understanding of what we read, in our own words building the basis with close reference to our research problem. We included folders for photos files taken during sessions at project sites, capturing the activities of learning and pupils' participation. In choosing our literature, we had a selection criterion of primary studies, and we employed the inclusion and exclusion criteria using key words, phrases and combination words such as: aquaponics, education for sustainability, blue and green farming technologies etc. We had access to several databases through the Aalborg University Library online webpage and the general public internet. However, we made sure that most of the publications we used were peer-reviewed and published in well-known conferences and journals. Given that aquaponics is a new phenomenon; as an example, for the English only peer- reviewed journals; in the beginning of the study, we had 391 hits for "Aquaponics" and up to 5,183 for "blue and green farming technologies" on the main library webpage from the year 1998 to 2017. We proceeded to zero in on those relating to school applications, excluding further those dedicated to advanced research level on the technical details of the technology itself such as: "effects of varying test parameters on aquaponics". In the end, we were able to obtain a reasonable number and to our best knowledge, adequate literature resources that are featured in our bibliography. The purpose was to remain focused on the primary school level applications of aquaponics.

4.2. Sustainable methods of food production.

Sustainable food production encompasses growing food in an ecologically friendly way with an ethically responsible approach. The sustainability terminology was defined by United Nations organization in late 80’s. The United Nation’s document from 1987 “Report of the World Commission on Environment and Development: Our Common Future’’ clearly characterized sustainable development as one that “meets the needs of the present without compromising the wellbeing of future generations’’ (UN, 2016; Mitcham 1995). Sustainable food production practices in contrast to industrial food production which among other practices applies the use of pesticides, fertilizers and other inputs should not damage the environment. They support and sustain local food production and communities.

4.2.1 Some sustainability challenges and prospects within food production systems.

The FAO’s current concern is about whether today’s agriculture and food systems are capable of meeting the needs of a global population that is projected to reach more than 9 billion by mid-century and may peak at more than 11 billion by the end of the century. Moving forward, these increase is likely to worsen issues, coupled with a lack of financial and physical access to food that meets nutritional recommendations as well as individual’s taste preferences (FAO, 2017; FAO, 2016).

Trends in consumption and market demand, especially for seafoods show a continued increase driven by technological fishing development and consumer awareness of associated health benefits. These drivers, in addition to diminishing and degraded resources for agriculture, forestry and fisheries such as land and water have led to a mismanaged food system that is unsustainable (European Environment Agency, 2016). Data from a recent (2016) FAO analysis of commercial fish stocks, showed that the share of fish stocks within biologically sustainable levels decreased from 90 percent in 1974 to 68.6 percent in 2013 implying, 31.4 percent of fish stocks were estimated as fished at a biologically unsustainable levels and therefore overfished. The global numbers since 1974 therefore depict an increasing trend towards overfishing. Based on the same report, the European Environment Agency recorded that around 89 % of the world's fisheries were either fully fished (58 %) or overfished (31 %), leaving only around 10.5 % underfished. This happened while the share of world fish production utilized for direct human consumption has continued to increase significantly in recent decades, up from 67 percent in the 1960s to 87 percent, or more than 146 million tonnes, in 2014 (European Environment Agency, 2016 c.f FAO, 2016a). Furthermore, Parker (2012) cited the UN-FAO estimates, that more than 40 percent of the seafood consumed worldwide comes from aquaculture and that production must double to meet the expected demand by 2030.

Water is a critical resource for food production. According to the FAO (2003), improving sustainable development and management of water for agriculture is essential to meet the world's growing demand for food, enhance food security and alleviate poverty. During the 3rd World Water Forum, the FAO Director-General Jacques Diouf is noted to have said:

"Efficient and effective water management in agriculture will generate the income for improved rural livelihood," ... "It is only under such conditions, that the development of health and education, and also the protection of the environment, will be ensured sustainably." (FAO, 2003).

Water is already scarce in many developing countries, and there is increasing competition for its use from industrial and domestic users. FAO estimates that by 2030, one in five developing countries will be suffering actual or impending water scarcity (FAO, 2003).

Currently high-input, resource-intensive farming systems have caused massive deforestation, water scarcities, soil depletion and high levels of greenhouse gas emissions. It is urgent that the agricultural sector produces more, with less by following principles of efficient resource use. To this end, proper understanding and deployment of new comprehensive strategies that can accommodate the needs and well-being of present and future populations are required. These can increase the provision of goods and services from agriculture in a sustainable way and synergistic benefits can be realized by integrating individual food production systems. It is expected that these approaches will minimize inputs, reduce pollution and waste, while increasing efficiency, earnings and sustainability (UN, 2014; FAO, 2016; FAO, 2017). Conserving nature and natural resources is in line with the concept of SD that is central to the UN agenda for 2030 (FAO, 2010;

International Union for Conservation of Nature and Natural Resources, 1980; UN, 2015). With an increasing awareness of the importance of a holistic approach to the above areas, this research work on aquaponics comes as timely act seeking to address in part the mentioned areas of concern.

To address the challenge of sustainable diets, The UN-FAO has suggested that food production systems be based on a range of factors such as: low-input-agro-ecological ways with limited animal husbandry, involve short-distance from production to consumption nets, products undergo minimal food processing and refining as well as the appropriate use of recent technological tools (FAO, 2010). In industrialized countries such as Denmark, sound approaches that integrate nutrition and ecology in an agro-ecological food production system termed as "organic food production" is increasingly being practiced. The system is supported by the European Commission, and it accounts for about 10 percent of the agricultural sector, and it is proving to be efficient in providing quality food with reasonable yields, while respecting the environment (McMichael, 2005).

In order to safeguard the sustainability of any actions taken, it is important to recognize that children have a role to play in SD. According to the United Nations (2017) children's interests need to be taken into account in the participatory processes on environment and development, because they are the ones that will inherit the responsibility of looking after the Earth. All key areas touching on the environment and development, health and nutrition, and poverty alleviation can be said to be anchored in education and literacy from an early age. Enhancing human skills for living in the world, so as to have responsible citizens, with lives and careers that meet personal as well as societal needs has necessitated the use of communication and collaboration as the tools for working. Technological tools in advancing ways of thinking such as learning, creativity, critical thinking, problem solving and decision making are now being used (UNDP, 2016). Education for sustainability that enhances SD of the food system through schools can be a good investment. It is therefore imperative that learning institutions for young people, be effectively used as avenues towards the realization of a sustainable future.

4.2.2. Sustainable approaches in traditional agriculture.

Today's traditional sustainable food production methods ensures that production practices used are sustained over time and do not have degrading impact on the nature. In this type of production; different practices are involved which include among others: the principles of multi-cropping-an agricultural method where several types of plants are grown in a field. The method may include crop rotation in different seasons or use two or more of diverse plant sorts grown closely to each other (intercropping), which results in a number of benefits for the plants. Soil quality is a significant factor in sustainable food production. To preserve soil quality, natural fertilizer in form of compost and animal manure is applied instead of using synthetic fertilizers. These natural products have a beneficial impact on the soil quality, they improve soil biodiversity and nutrient absorption by the plants. Mulching is also a practice that can reduce weed growth, keep the right temperature and moisture level of the soil. The concept of sustainable agriculture rejects the idea of using Genetically Modified Organisms (GMO) seeds in food production due to the yet unknown potential impact on the environment and human health. Moreover, practices such as water conservation in form of the so called low volume irrigation and rainwater catchment is commonly used (Sustainabletable, 2016).

Sustainable farming is no longer associated with rural areas of the land only, but it can be part of populated urban spaces. Urban farming gardens can be found in city places from small backyards to rooftop spaces. Vacant or neglected urban spaces transformed into gardens would bring more green areas in the cities. Building rooftops gardens can make efficient use of a limited areas with some positive environmental effects by providing additional insulation of the buildings, which in turn could result in lower energy used for both cooling and heating of the building. The new ways of food production slowly have changed the perception and manner of how plants are grown and distributed alongside the food chain with an intention of bringing food production closer to cities and local communities (Sustainabletable, 2016).

4.3. Benefits of urban agriculture.

Today's urban agriculture with access to modern technologies could be applied in both developing and developed countries with different levels of economic and social improvements in local communities. In the developing countries the key driving aspects supporting the sustainable urban agriculture is mostly motivated by food security and financial gain reasons. In the resource abundant developed western countries, social networks bond by shared values, belonging to a community and nature are people main drivers for movement for sustainable urban development. There are number of advantages connected to urban agriculture.

In a study conducted by Alaimo and colleagues (2008) people involved in urban gardening had tendency to consume more fruit and vegetables on regular basis. Additionally, people growing their own food and those who are actively involved in planting and taking care of the food gardens have greater tendency of trying new types of vegetables (Alaimo et al., 2008). Greater acceptance and consumption of locally grown produce from urban gardens may be due to the fact that people perceive those products to be more tasteful and attractive from fruit and vegetables purchased from supermarket (Hale et al., 2011). The nutritional quality of produce coming from urban farming is superior over the ones transported to the cities. The time between harvest and food preparation (farm to table concept) is cut down to the minimum avoiding nutrient lost. Apart from industrial food processing methods which may add to some nutrient lost, more importantly storage duration of the produce is a significant factor in degrading product nutritional quality (Rickman et al., 2007). The advantages of having one's own garden eliminates the issue of product storage radically.

Apart from the evident positive impact of urban agriculture on nutritional health, food choice behavior and educational potentials, urban agriculture may play an important role in poverty alleviation and social integration in local communities. There is number of examples where municipalities started gardening projects to engage people actively in order to better integrate them into the city social network. By taking an active role, working and spending time together individuals have the feeling of doing something constructive in supporting the community. Prospect for having urban gardening could add to physical and mental relaxation for the local population by providing leisure opportunities. People taking active role in urban gardening commented the fact of improved physical form. The reason for it is that taking care of a garden requires physical activity from digging to bending up and down, which in turn may be beneficial for the health. Many people stated that not only working and taking care of the garden contributes to the daily amount of activity but the fact of getting there by either walking or cycling (Kingsley et al., 2009). In the study of Wakefield (2007) one factor of improved mental health could be the fact of gardener's appreciation for interaction with nature which is "relaxing and calming'' for them. Green spaces provide a soothing enclave in often populated city areas. Secondly, municipalities with gardens tend to notice improved "community health'' which is mirrored in better social interactions among people, increased feeling of pride and empowerment (Wakefield et al., 2007). Investing in neglected, unused and open city spaces often exploited as dumpsites in any form of urban agriculture may have positive impact not only aesthetically, but also in making cities greener and more clean. This type of entrepreneurs as "green'' productive spaces could serve as a natural barrier from expanding industrial or housing zones, thereby improving community's livelihood (RUAF, 2016).

In educational system, schools having its own garden integrating hand-on gardening activities in the educational programs can experience positive link between higher fruit and vegetables intake and school gardens as in a case shown among mid primary school children (McAleese & Rankin 2007). Hands on practical activities in the gardens reflects in increased theoretical dietary knowledge among children. Children taking part of the garden education tend to better describe any potential nutritional benefits in the human body caused by the consumption of greens. Despite the limitation of the data supporting school gardening and its claims, it has potential to positively influence children's knowledge, behavior and awareness about the surrounding environment (Lautenschlager & Smith, 2007).

4.4. Urban agriculture and school gardens in Copenhagen.

There is a number of city urban farms around in Copenhagen, situated in various location from rooftops, halls to peri-urban farms on the city outskirts (Opengardencph, 2017). The agricultural framework of activities taking place it those institutions range from basic plant growing to social and educational arrangements. School gardening in Denmark has a long tradition and nowadays gardens are very popular in the Danish schools. There has been great interest in teaching young generation about food origins and environment. Officially, the Association of Copenhagen School

Gardens (Københavns Skolehaver) is a formal institution running the school gardens project. Physical activities in which children are involved and lecturer ability to connect it to the theory is seen as a very efficient teaching combination. This was stated by the school gardens responsible; Camilla Friedrichsen:

"Good schooling is all about linking theory with practice. Here in the school gardens, children can touch, do, feel, and experience'' (Kbhskolehaver, 2016).

4.5. Importance and need for novel food production with focus on aquaponics.

Other methods of sustainable food production are applied and practiced around the world. These includes among others: hydroponics; a novel production technique in which plants are grown in soilless environment with constant flow of nutrient solutions that provides all necessary nutrients to the plants roots (Benton, 2005), and aquaculture which predominantly involves production of fresh and saltwater fish and other aquatic organisms under controlled conditions (Romanowski, 2007). Then there is aquaponics; a food production method combining aquaculture and hydroponics in one closed loop integrated system (Nelson, 2008).

On a global scale, the FAO (2016) reported that: "Currently, aquaponics serves communities with limited freshwater resources, limited land, and high sale prices of fresh vegetables with successful aquaponics interventions by the FAO being conducted in Gaza and the West Bank and in Ethiopia. Aquaponics support was recently highlighted as a target of the Sixth Meeting of the Working Group on Aquaculture of the Regional Commission for Fisheries (RECOFI) in Muscat, Oman and a technical publication Small-scale aquaponics food production: integrated fish and plant farming, was recently developed by the FAO Fisheries and Aquaculture Department. It is being translated into Arabic to support further aquaponics development in the region and the English version is available online." (FAO, 2016).

4.5.1. Aquaponics in relation to sustainable food production: economics and health diets perspectives.

In considering sustainable food production, it is worthwhile to look at the commercial and economic prospects of the method chosen. The increasing global population with a high demand for organic fruits, vegetables and herbs, off-season availability and demand for sustainable & natural foods without chemicals or pesticides may be some of the reasons collectively driving up growth in the aquaponics market in the recent years. The associated low cost in terms of lesser preparation time of harvested produce, is attractive to both producers and consumers. These factors together with an increasing awareness about the health benefits of fish consumption across globe has supported the growth of the aquaponics market (Market Research Future, 2017).

In the EU, Eco-Innovation funded projects like EcoPonics, the European Cooperation in Science and Technology, COST Action FA1305, have been carried out in countries such as Iceland and Germany. Innovation companies have collaborated with universities, aiming at implementing commercial and competitive aquaponics production systems (EcoPonics (n.d); Goddek et al, 2015). The increasing use of aquaponics for research purposes can also be said to be driving the market growth; institutions are now using aquaponics for research and development activities. In an international survey on commercial aquaponics production and profitability, Love and colleagues (2015), found out that gross sales revenue and profitability were higher for operations that diversified revenue stream by selling non-food products, services, or educational trainings. These findings show that, besides deriving direct income from produce sales, there are other avenues which can be utilized, making aquaponics uniquely appealing as a means to earn. We can therefore argue that, innovative technologies in aquaponics can be used to increase cash flow thereby influencing the growth of the market.

In addition, the aquaponics farming technique is adaptable to different climatic conditions; it is not dependent on the seasons, soil or rainfall on tilled land. This makes it more attractive in areas that have been greatly affected by climate change. These factors have led some investment advisors like the Market Research Future to speculate, that growth in the aquaponics market at the Compound Annual Growth Rate (CAGR) will be at 7.5% during the period 2016-2022 (Market

Research Future, 2017). As aquaponics manufacturers continue to focus on research and developments activities to improve its efficiency, global aquaponics remains fragmented in various application sectors like: for hobbies, for commercial purposes, for educational institutes research and for home food production. This can be seen as an opportunity to key players for investment, thereby giving several possibilities to establish new trends for the aquaponics market.

For optimal nutrition, the overall food quality and quantities are important aspects to consider. This is also dependent on tasty products with a high nutrient content that has minimal or no contaminations by chemical toxicants. Products raised through aquaponics fits well with the organic agro-ecological method. The nutrient contents can be said to be much improved when compared to alternative systems, since no chemical or toxic contamination occurs. This is in agreement with recent reviews on agro-ecological production as documented in literature (Lairon, 2010; Dangour et al., 2009; Rembialkowska, 2007). In addition, Saha, Monroe and Day (2016) in their research on investigating the growth, yield, plant quality and nutrition of basil under soilless agricultural systems, also found out that there was increased yield of aquaponics basil. i.e. 14% more in height and 56% more on fresh weight when compared to hydroponic basil. Comparable yields have also been reported by Delaide and colleagues (2016), their research showed that aquaponics and hydroponics treatments exhibited similar ($p > 0.05$) plant growth confirming that AP systems can be viable alternatives to conventional hydroponic systems (Delaide et al., 2016).

4.5.2. Aquaponics use in other schools around the world and in Denmark.

Aquaponics as an interdisciplinary educational tool could be used in multiple ways. It could be implemented on all education levels in the current curriculum to better prepare future generation qualified workforce by giving the pupils possibility of active learning with hands on activities. The rationale for using aquaponics is supported by possible improvement in students learning outcomes, development of new ideas, creativity, communication skills, active engagement with peers which could further develop social skills. Aquaponics should be treated as a living organism educational tool used both to grow plant and fish in school settings incorporated in academic subjects with an advantage of hands on practical activities. There have been number of schools around the world successfully implementing aquaponics. Countries such as Australia and USA are ahead of other countries in number of schools which implemented the tool as well as technological development of the system. Generally, in available literature sources there is a fairly good description of the technology, different system set up, technical requirements and even description of aquaponics implementation into individual subjects in the curriculum. Nevertheless, available literature describing pupil's improvement of the learning outcomes with the help of aquaponics is very limited. Information of successful aquaponics system implementation in the school in one regard does not guarantee long term continuation of the program and tells little about usefulness of the system in improving children's knowledge. There is need for aquaponics pre and posttests, interviews and updated literature review in order to evaluate the real impact of the aquaponics system on improved food literacy skills of the children.

Aquaponics was introduced in Rossmoyne Primary School in Australia (Rossmoyneps, n.d) engaging students in scientific investigation as well as in Girraween Primary School, where children as early as 5 years old during Agricultural education. The Girraween school can be perceived as an indigenous example of how to build inexpensive indoor aquaponics system consisting of a bathtub with several plants floating on the water surface which is pumped from small tanks containing goldfish and barramundi (Figure 2). Teacher Ashlea Lidbetter admitted that it may be challenging to make children understand how all parts are connected, but is never too early to start aquaponics education as long as teachers focus is on simple facts "It provides scope for them to go beyond the curriculum and to take the learning further; it's important to have these exciting things happening in the school," she said (Abc, 2016).

Figure 2. Dirty water is pumped from the tank to the bathtub which contains potted plants including tomatoes and basil. The plants utlilize the fish poop as nutrients and the clean water which is then recycled and pumped into the fish tank. (ABC Rural: Lisa Herbert). Source: (Abc, 2016).

Teacher Mike Burns from Westfield Primary School in Western Australia helped himself in getting aquaponics system up and running. He complimented the system multidisciplinary appliance where children can learn many things from chemistry, biology, physics and even cooking. In order to be successful as he mentioned it took committed, engaged and enthusiastic teacher to give things a go and push the limitations. School build environment could add some difficulties in terms of aquaponics implementation by legal regulations imposed by the government as well as practical issues of system care during summer breaks. No much is known about the system status today, since the homepage (Backyardaquaponics, 2012) has not been updated from year 2013.

In aquaponics journal prepared by Nelson and Pade (2007) in the Aquaponics Journal 3rd quarter of 2007 named several schools, institutions and educational centers which successfully managed to implement the aquaponics system into educational curriculum. Shrewsbury Elementary School in Pennsylvania used aquaponics to teach fourth grade students in science lesson how to care for plants and other living organisms. Tasks of feeding the fish and fostering the plants were distributed among the pupils and math skills were used to calculate grow cost of the plants which was later used to plan the budget to purchase seeds and other supplies for next year. In few instances in post implementation interview children commented that growing and taking care of the plants made them "like to eat vegetables''. In Canby High School in Oregon introduced already in early 90 programme integrating aquaponics, biological science and marketing with both theoretical and practical applications. Students apart of taking the care of the system they were involved in water tasting and tissue culturing in aquaponics lab. They even build mobile greenhouse aquaponics system to demonstrate the technology in local schools and communities. Tunstall High School in Virginia demonstrated another integrated approach in teaching students about aquaponics, genetic engineering and biotechnology with the purpose to better prepare students for the future diverse career opportunities. Students studied specific areas from biotechnology, plant science to environmental impacts of aquaponics. Lectures were combined with individual sessions in the lab researching topics from water quality, nitrogen cycle to plant anatomy, tissue culturing and plant and fish reproduction. Aquaponics in The Island School Bahamas was used as a model and research possibilities for sustainable food production in developing part of the world. The system in the schools was used as a training device where students were responsible for monitoring and refinement of the aquaponics. Aquaponics as an educational tool was also used in institution other than schools. Pendleton Juvenile Correctional Facility in Indiana used aquaponics in resocialization by active hands on learning activities among teenage boys in maximum security prison. The boys were responsible for the system maintenance and operation, carrying for the plants and feeding the fish. One of the caretakers and teacher Philip Greenburg mentioned that apart from teaching the subjects he would like to show how to be reliable and trustworthy employee “The real benefit of the aquaponics that I see is that the boys take pride in of what they are doing’’. Educational centers such as Sid’s Ponds Aquaponic Center in Ontario, Canada (Pondclub, n.d), and Herring Gut Learning Center in Port Clyde, USA (Herringgut, 2016) provide opportunity for teachers, students and general public to learn more about aquaponic technology. There are number of tutorial, tours with information tailored for specific group of visitors and students workshop. Students from local high schools (Georges Valley High School and Rockland Alternative Education Programme) participated in building, monitoring and taking care of the system and took initiative in small business by selling aquaponics basil and other produce to the local restaurants and groceries. Herring Guts provide educational programs: Short Term Courses, Summer Programmes and Independent Studies, where students take part in hands-on activities and experiments using aquaponics technology to show model of nitrogen cycles, learn about biology, fish anatomy and range of other subject from chemistry, math, ecology to business and management (Nelson, R.F., & Pade, J. 2007).

In School Planning and Management magazine mr. Bruce Haxton and ms Rebecca Nelson (2015) in article “Four Examples: Schools Aquaponic Teaching Tools’’ described four educational institutions in USA which successfully either created aquaponics educational programs or implemented aquaponics into existing curriculum. One of the schools mentioned in the article is Canton elementary school in Georgia which has indoor aquaponics system and AQUA lab on the aerial of around 75^2 meters build at the cost of around 4000 USD (Figure 3). The idea of learning was based on pupil’s engagement and imagination supported by the frame of STEM educational curriculum (the STEM concept will be described in the next section). Lessons are developed by the teachers to meet pupils needs, to encourage children to take an active learning role instead of being passive recipients of knowledge and to prepare them to solve unforeseen yet problems of the future. The living ecosystem in the lab has number of fish and plant for experiments as well as pupils learn how apply easy-to-use data loggers and computer graphic and analytical software.

Another school mentioned is the Safe Harbor Academy located in Versailles, KY is an alternative learning institution working in partnership with young adults, families, and local community. The 28² meters in school aquaponics system was constructed at the cost of 4000 USD (Figure 4). The education integrates project based learning (PBL) and other initiatives through aquaponics. The school closely cooperated with local businesses to find out what skills, characteristics and qualities are necessary to possess by the future employee to succeed on the market.

Figure 3. Student are preparing to add plants to the aquaponics system at the Agua Lab at Canton Elementary School. Plants will float on rafts on the surface of this tank, with the roots dangling into the aerated, nutrient-rich water. Source: (Haxton and Nelson, 2015).

Figure 4. a Clear Flow Aquaponics System at Safe Harbor Academy. Source: (Haxton and Nelson, 2015)

BTI aquaponics is one year long high school programme at Baker Technical Institute, in Baker City, Oregon. The aquaponics system is build indoors on the area of 140² meters at cost of around 6000 USD (Figure 5 and 6). The curriculum is based on STEM education with broad focus from water quality, plant and fish sciences through food security & safety, sustainable agriculture and biological engineering. The programme is based on four main pillars: 1) research, planning, designing and building aquaponics system from the bottom for food production. 2) Designing collaborative business model for the produce to be sold locally. 3) Explore local career potentials in the field of aquaponics supported by excursions to the Department of Fish and Wildlife in Oregon. 4) Participation in service learning with local council, career partners and summer internship. Figures 5 to 6 illustrate some of the student activities that they get involved in as a part of their learning process.

Figure 5 Water quality testing is an essential part of aquaponics food production. Here, a student in the BTI Aquaponics program checks temperature. Source: (Haxton and Nelson, 2015).

Figure 5 Students harvesting aquaponically-grown lettuce that will be used in the school lunch program at Baker Technical Institute, Baker City, O. Source: (Haxton and Nelson, 2015)

Washburn High School, located in northern Wisconsin, over a year designed and built 93² meters aquaponics system in a outdoor greenhouse at the cost of 8000 USD. The high school students were responsible for putting the system together under technology education department supervision. Initially, the facility was used during semester course where students took part in hands-on activities associated with aquaculture as well as hydroponics. The task consisted of maintaining nutrient, bacteria balance within the close loop system and measuring water pH, fish growth while taking care of the plants. During the programme progression apart from hands-on PBL research component was added as an integral part of the course, where students were individually researching topic of interest within environmental science field (Haxton, B. & Nelson, R. 2015).

In 2012 a higher education Department of Biology at the University of Wisconsin–Stevens Point (UWSP) with cooperation with a private entrepreneur offered 3-credit, full semester Introductory Aquaponics Course, which was to believe the first of its kind. The private-public partnership was believed to initiate a new step in the development of the aquaponics technology by offering university level education. The curriculum was combined with online self-study lectures supported by and live chat lecturer instruction and aquaponics hands on activities in the nearby greenhouse aquaponics center. The course topics covered a range of disciplines starting from the history of aquaponics, system components and daily operation, environment control, plant and fish biology, pest management and record keeping to issues concerning economics and marketing. The logical rationale for the programme stressed the urgent need to educate professionals to fill future jobs as aquaponics engineers and managers (MotherEarthNews, 2016).

On European platform countries such as Switzerland seems to have a pioneer role in introducing innovative technologies in education. The document written by Junge and colleagues (2014) is one of the few available documents (as for December 2016) describing the aquaponics system education curriculum in details, together with evaluation of the teaching outcomes at the end of the course date. Between 2007 and 2008 primary school in Zurich, Switzerland introduced aquaponics "system thinking'' concept in teaching 7th grade students connecting fish and plant culture system in sustainability education. In practice six aquaponics systems were built by the students who were themselves responsible for system operating and monitoring. This was done on a daily basis and data such as measurement of the plant, fish feeding, water temperature check was performed, documented and shared between groups who worked on the same model. Children during theoretical lessons apart from being introduced to the aquaponics model system and regulations were taught important relations among aquaponics components. According to the course designers' system thinking (thinking in models, interconnected and dynamic thinking) is a necessary competency, an important ability for children to possess in order to have better overview over complex problems in real life world situations. The idea behind the outcome evaluation was to check children's system thinking on example of being a farmer and included questions such as; "why did the farmer put manure on his fields?''. At the end of the course in the posttest the students' ability to think in a systematic instead of linear way was improved (Junge et al., 2014).

University of Applied Sciences, Institute for Natural Resource Sciences in Zurich, also in Switzerland applied aquaponics, but on higher educational level in BSc and MSc programmes. The programmes taught on ZHAW Aquaponics Lab addressed different requirements depending on the level, relating to number of factors from construction size, system control, energy needs, treatment and use. The aim of the institution was to promote sustainable development and train specialist such as the aquaponics farmer to build and operate aquaponics systems in the future. The role of the scientific research should lead to optimization of the technology and limit any potential safety issues involved (Graber, Antenen and Junge, 2014).

4.5.3. The use of technology in learning: aquaponics as an educational tool.

The use of technology in schools can impact teachers in disseminating their responsibilities as educators and as lifelong learners themselves. In the continual challenge for teachers to develop knowledge and skills about what to teach and how to teach, technology becomes an important consideration. It can be used to facilitate social interaction and communication among learners in class, within a school, between schools and around the world on social media. Public participation and the role of schools are mentioned in AGENDA 21. Most specifically, there is a concerted effort to mobilize communities through schools and local health centres so that children and their parents can become effective focal points for sensitization of communities to environmental issues (UN, 2017). It is on this basis that we identified a niche for aquaponics to be used as an educational tool at primary level to enhance food literacy and foster SD in the long run. On the technological aspects, the state of the art is advancing rapidly on aquaponics with new techniques and technologies such as decoupled designs and automated sensor controls being developed as stated earlier, but the details of such research is beyond the scope of this study. However, considering that it is a novel science and technological approach to producing food, essential knowledge and understanding of how the system works and its meaning is required, preferably at an early age. In other words, aquaponics could be turned into education for sustainability. There is potential for applying aquaponics on a wide spectrum of academic disciplines, with a possibility for practical incorporation into existing theories within the educational curriculum. We realized that for such systems to bring about change; there is a need to disseminate knowledge and skills that can be further shared and practiced among populations and there is no better platform to lay the foundation than through learning institutions, especially starting with young children.

4.5.4. Teaching applications of aquaponics in STEM education.

STEM in an acronym that that stands for disciplines such as science, technology, engineering and mathematics. The short terminology is often used when talking about educational policy and curriculum. Aquaponics could be an excellent tool incorporated in many school subject from science, agriculture, math and economics. The teaching programme could run for example through the entire semester, allowing lectures to present the topics as the plants and fish grow. In order to achieve successful learning, plan additional teaching tools and supportive resources for optimal educational curriculum would be needed.

In paper published by Wardlow and colleagues (2002) described how University of Arkansas, USA established AgriScience Education project to develop and distribute aquaponics related educational materials that primary teachers could use in classes. This was done after successful pilot-tested prototype of classroom-scale aquaponics unit which was constructed in late 90's. Teachers who took part in this programme borrowed a small scale aquaponic unit together with manual instruction and set of laboratory activities for students. In the beginning of 2000 already 16 aquaponics units were used in 38 in school classrooms in Arkansas, Kansas, Oklahoma, and Missouri. The educational curriculum provided was developed in cooperation between the project members and participating teachers. The materials were constructed for every individual subject and activities e.g. in mathematics; Determining Water Cycle Rate and Feed Conversion Rate, in chemistry; Monitoring NH3, Dissolved O2, pH Levels checks and The Nitrogen Cycle, in physics; Evaluating Pumping Efficiency and Power Factor and lastly investigating Plant Structures and Functions in biology lessons. In informal evaluation process teachers were very positive about having the system in the classroom project stressing students interest and possibility for research provided by aquaponics (Wardlow et al. 2002).

Today there are examples of how aquaponics is helping teachers to use the technology to teach STEM education, because it is a natural and practical way to address all subjects (Freshfarm, 2015). Several private initiatives e.g. Ecolife (2016) provides unconventional aquaponics educational programmes for teachers, which are available online. The rationale behind using aquaponics as teaching tool is to interactively engage students in STEM concepts. Aquaponics USA (2016) provides a practical 33 pages' document "Bringing Your Classroom to Life'' dedicated to the teachers wanting to have the technology, with all details about STEM aquaponics education. Lastly, Nelson & Pade (2016) provides Aquaponics Curriculum package consisting of guidelines for the teachers, tutorials for complete lessons supplemented with student manuals and educational quizzes. The Aquaponics Curriculum package is intended for 7-10 grade students to teach many principles of science, agriculture, math and business. The Curriculum package contains complete information and tools for teaching aquaponics. The package consists of whole lesson plans, lesson outlines, time period, objectives, activities, tests and answer keys (Nelson & Pade, 2016).

These arguments are based on alternative learning and teaching approaches that form the basis for our conceptual framework as presented in this thesis. These will include: Learning by doing experiential learning as championed by John Dewey's philosophical and psychological arguments on experimentalism in "Education and Experience", Lev Vygotsky's Zone of Proximal Development (ZPD) theory, Kolb's Experiential Learning Theory (ELT) model, the Science Technology Engineering and Mathematic (STEM) principles, Problem Based Learning (PBL) and the Knowledge Triangle (KT) policy paradigm model. In this context, we support the learning processes that give more regard to the changes that will occur in future, recognizing that we live in a society where change is the rule rather than an exception. That being said, considering the evolving nature of aquaponics, it is important to recognize that, with more and more research and trials taking place around the world, information around the practice will develop continuously. Educators using aquaponics will be required to update their understanding and practice regarding its operations, maintenance and care in order to help students learn effectively.

5. Methods – study design.

5.1. Considerations for the choice of action research.

We assessed the suitability, feasibility and the ethical aspects of the project in order to achieve our goal as presented in our problem statement. After identifying the purpose of our research and establishing links with our assessment, we were optimistic that action research would produce findings that could answer our research question. We started the planning phase by first establishing that we had sufficient time to design the full research from building the system, to collect data and finally analyzing and presenting our findings for which this thesis is about. Being a low cost project, we were able to gather all the resources available to us such as: securing adequate space for the setup; made easy and convenient as illustrated in figure 7.

Figure 7. Unused aquarium and unutilized space at the school laboratory.

Coordinating the purchase of all the equipment and material used in building the system, transportation arrangements etc.). We presumed that the research was of a low risk in relation to ethics. However, we ensured that all harm was avoided to the participants throughout their involved with the project and as a precaution, we obtained verbal informed consent from all participants. We committed to guarantee confidentiality of the information given to us during the research.

5.1.1. Theoretical pre-evaluation of the technology to be implemented.

For the pre-evaluation, we took an adaptation of Eady & Lockyer (2003) approach with some criterion that we thought fitted well with aquaponics. Eady & Lockyer in their work on “tools for learning”, presented an example that can be used in Information Technology (IT) digital learning with some criteria and questions that educators might ask themselves when evaluating an educational software, applications and resources. Some of their considerations would be used as well in the case of aquaponics, and we adapted them as our key consideration questions under the subsections below:

- Age/year level: will the system built be appropriate for the age and year level of the students and the content level of the system appropriate and sufficient? In our case; positive for ages 10-19 years old.
- Curriculum links: Are there links between the content/functions of the system and the expectations of the curriculum and will the system help teach the curriculum in a new or a different beneficial way? Positive to us: in our earlier discussions meetings with the teachers, we established some relevant areas that the teachers would use the aquaponics for, that are in line with the curriculum.

- Instructional content: Is the information provided accurate, complete and current? Are the sources reliable? And does the content encourage higher-order thinking and also present multiple perspectives? Positive for the educators and users; we were able to provide an aquaponics book for basic understanding of the operations, and we also provided some links and online resources that the educators would use for free. They would also get some extra material upon subscriptions for inspiration on the various applications of the system beyond their own creations or imaginations.
- Engaging and interactive: Will the learner(s) be actively involved in using the aquaponics? Will feedback be provided in an appropriate and meaningful way? Positive, as intended with the educators.

Some of these consideration were reserved and modified to make part of the questions that we used in the interviews for collecting data that would help us in answering our research question.

- Assessment: Will assessment tasks be included or can the teacher develop relevant assessment tasks that link to the use of aquaponics?
- Flexibility: Can all aspects of aquaponics be integrated easily into classroom activities and can it be used for multiple curriculum units?
- Living things: Do they support or distract from the learning activity?
- Usability: Is the aquaponics easy to use and intuitive?
- Technical considerations: Does the system work consistently? Are there special technical requirements for using it and does the school have access to those requirements?
- Support materials: Does the aquaponics unit have some forms of help (e.g. manual, some related online tutorial, etc.)? Are teaching support materials or online resources available to help teachers embed the aquaponics into lessons?

With the above considerations in mind, we recruited project participants, followed by continued collaboration meetings as necessary, subsequent interviews, and actual buildup of the system. The specific details on sampling, system design to the final implementation at the school are given in the following sections.

5.1.2. Sampling.

We considered the Organization for Economic Co-operation and Development's (OECD's) Knowledge Triangle (KT) policy paradigm model in coming up with our list. The objective was to have a complete representation from the 3 key sectors players that make the KT. These were constituted as from: a) Business: we had the entrepreneur (BioArk)- one aquaponics expert, who is a technical bio farmer, also representing a community based social entrepreneurship at Osramhuset in Copenhagen. b) Research and Technology- we represented that, as researchers from the University of Aalborg-Copenhagen Campus) and c) Education- represented by the teachers and pupils of upper primary school; Blågards Skole in Copenhagen. - a total of four teachers were conveniently recruited from the school, including the headteacher on the basis of their willingness to participate. For the focus group interview, only four (4) students from a class of fifteen students that were introduced to aquaponics participated.

5.1.3. Design and construction of the aquaponics Unit: System design principles and elements taken into consideration.

We considered the following design principles, integrating concepts learnt on design intent, borrowing greatly from the knowledge and skills we acquired from a previous design course (Food Concept Design) offered in the Integrated Food Studies (IFS) programme at Aalborg University. While some of the considerations are not to unique to the aquaponics system and can apply to other setups, the objectives of the design elements were such that, they would facilitate learning about all the aspects of sustainability in relation to food production while demonstrating some convergence with aesthetics. These principles included:

1. Environmental awareness: this was to enhance the understanding on what essential elements from nature are needed for food production like water and light. The design was meant to create a sense of how resources such as water and space can be managed and used efficiently e.g. through "nutrient/waste" and water cycling. The design was intended to give a possible understanding of ecosystem and biodiversity dependencies and how they can be restored or preserved through minimizing or eliminating pollution and its effects.

The aquaponics system mimics an ecosystem with an integrated design, that incorporates food production in a closed-loop nutrient cycling; this was to foster the perception of an environmental aesthetic that promotes awareness of function, and ensuring that the design elements in terms of actual material used are both safe and accessible to all the users. On the biodiversity- the mimicking and enhancing the biodiversity by ensuring all production needs to be met was made possible through inclusion of design elements like the more than one plant species used (tomato, zucchini, coriander, mint), provisions for continuous recirculating water, a growing medium for root support replacing dirt or soil, and for keeping the microbial community (the beneficial bacteria) and the worms. Shaded light accesses from the sun by placement close to a window was made possible and to engage the users at the human scale, where awareness would be fostered; that ecological services are connected to the system.

2. Social cohesion: here, user experience was a key consideration given that creating a draw/attraction was critical for the children. The design was made in a way to enrich user experience by creating a multifunctional space that is attractive and engaging. This was meant to develop an appreciation for aesthetic values associated with food production and consumption. The design was meant to be inviting to the kids fostering interaction among themselves around the learning environment. It was setup to facilitate an assembly space around the system thereby giving them an equal opportunity to learn as shown in figure 8. Even though it was placed closed to a window, the consideration was to facilitate a central placement where all viewers could go around it with ease. The set up would offer more access to a wider audience, easy to assemble and move around whenever need would arise. The overall design aim was to create a multicultural, multi-ability level system that would be accessible, developed technologically in a fairly straightforward way.

Figure 8. Pupils gathering around a newly built aquaponics system.

3. Economic sense: It was important to install a system that supports production of actual food produce, that can be consumed and show how technology can be used in a smart way to produce food in a cost effective way- the food plants planted were: tomato, mint, zucchini and coriander which hopefully will grow to maturity to harvested and consumed.

4. Creating attraction or a draw: we incorporated a variety of aesthetic considerations, this included features and elements/materials that are visually interesting in shape and form. We presumed that people get drawn to where others congregate, and where there are signs of activity and life, as found in flower gardens. We think that these features can let individuals explore curiosity. On that note, the children would be drawn to the living plant materials and fish found in the aquaponics system. Since the vision was on sustainable ways of food production, we worked on the premise, that people would be drawn to features that emphasize or exhibit that characteristic; where they could see the appropriateness of the technology, its productivity, where can be able to grasp it and possibly replicate it. For purposes of labelling and identification, we proposed that the Classroom aquaponics installation be called: "Adventures in Senses Art Aquaponics (ASAA)" but this was left for the pupils to decide, and chose a name that they would like best. For the fish tank, we settled on a transparent glass to instill a sense of mystery, a feature that encourages interaction and provides for enhanced visual sensory experience – the glass material allows individuals to see the movement and activity of the fish in the fish tank unlike using opaque materials for the fish tank. The children had an opportunity to touch the fish while transferring them into the tank and also to smell the young plants aspects which is illustrated in the learning cycle theory part of this thesis. The aim was to invoke some caring and fun sensations at the same time. The key consideration for the setup was to

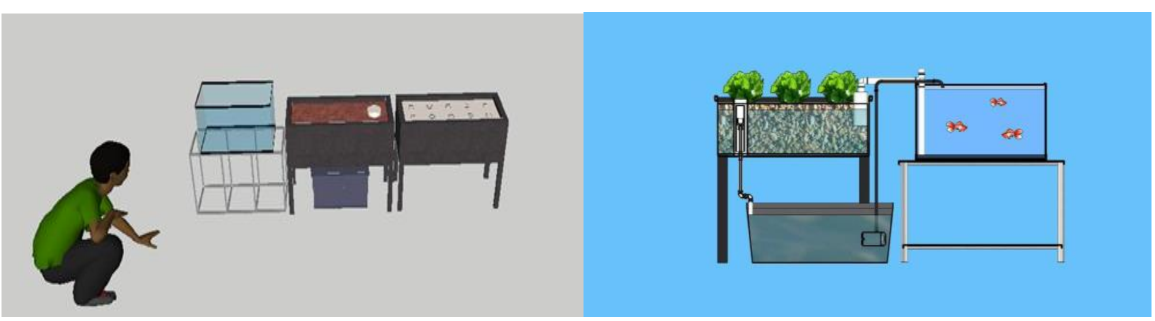
introduce a break from the usual classroom style teaching. Since the space was typically used for normal laboratory science classes, the design was an attempt to integrate or complement the surroundings, while also maximizing on aquaponics use of space efficiencies.

5. Set up functionality: We aimed at working towards balance and unity while at the same time being optimal to meet the requirements of the designated plants and animal life. We sought to create microclimates that are comfortable for the fish welfare, balancing their requirements for sun exposure while ensuring they are shaded and sheltered from strong winds. For the actual materials elements, we considered features such as the geometrical shapes of the fish tank, the size and dimensions in relation to the biomass density, the type and properties of media used for the grow bed; our choice being as follows: a) Grow media: for increased surface areas to the microbial habitation, an average size of 7mm in diameter was chosen for the gravel type that was purchased from a local store. The media was washed reasonably to remove excessive impurities as illustrated in figure 9 below.

Figure 9. Active participation by researcher in preparation by washing of the grow media.

b) Tank design and sizes: we used a regular rectangular shape glass aquarium as the fish tank with a sump tank of a similar shape fitting under the grow bed. The sump tank was approximately 1.5 times the size in volume as the grow bed, since it was needed to be able to collect all the water from the grow bed when drained. The volume taken up by the media in the grow bed reduced the need for having a larger sump tank. We minimized the height to which the water had to be raised by pumping from the sump tank to the fish tank accordingly to reduce power consumption. c) The biomass of fish: deciding on the ration can be challenging and this depends on various factors such as the species of fish and plants used and the stage of development, in our case the quantity was mainly limited by the volume of the aquarium used. Our expert resource (Lasse, 13:20), while helping with design features had recommended using as a reference, maximum fish biomass that aims at keeping the fish density at 20kg/m³ water. The system we designed was launched starting with 8 fingerlings of goldfish whose age and weight was not determined yet and a mix of plant seedlings and seeds that included one zucchini plant seedlings, several corianders seeds, a single tomato seedling and a few mint seedlings. Strict observance to plant: fish ratios was not kept, as the unit was only for testing purposes. However, a basic consideration was that the lower the density for both plants and fish the better, in order to reduces stress level.

d) Choice of the water pump: We started on the premise that the water flow rate must be approximately twice the volume of the grow-bed per hour based on Lasse's recommendation. An example that he had given earlier on from previous meetings was: for 500 litres grow bed, one will need a pump that can do 1000litres per hour; the reason is that the whole volume of grow bed should be renewed twice per hour. However, some time is lost due to the media media volume itself, this means the water volume it is renewed and filled up much faster than for the intended 30 minutes. - this is considered to be good for the aeration of the grow beds for the plant roots, the microbial community, and the fish as well. With this consideration in mind an air pump was not installed from the onset. To achieve this, an energy saving Eco-Pump, PondPumpNP-650 from Aqua-Nova rated 8W, 650L/h was used. The following figures 10-14, show the progressive work from sketching of the system to a final product that is fully operational.



Figures 10. a:The original sketch design of the aquaponics system, and b: The final design sketch of the unit.

Figure 11. The finished construction of aquaponics system and final testing at Osramhuset.

Figure 12. System set up at the school site for cycling to establish microbial environment (Day 1).

Figure 13. Pupils introducing fish to the system after two weeks (Day 2).

Figure 14. Fully operational aquaponics system at the school after approximately three weeks from day

For all the components and materials used, a budget was drawn in consultation with Lasse, and it is presented in the table 1, with links to retail and online sources for purchase.

Table 1. An estimated budget for the aquaponics components/materials used.

Extended Masters Project: Aquaponics school system setup budget

An estimate in DKK for the Aquaponics Components/Materials

Materials	Cost (DKK)
• Fish Tank/ materials for construction. o Second hand aquarium	0 - schools aquarium
• Sump tank/materials for construction. o Smart store box , black	230
• PH, ammonia meter reading equipment. o Pond lab test set	250
• Place to Grow Plants/ materials for construction. o 2 x Beds (1replacement) ▪ Siphon bell ▪ Gravel/Leca	600 350 90
• Water Pump. o Tunze	600
• Air Pump (optional) o airpump, airstone, tubing	250
• Fish and Plants (initial stock) o 10 goldfish	300
• Irrigation Tubing (Pipes and fittings)	150
• Others. - cup drill and misc.	150
Total	2970

5.2. Methodology for data collection.

This section of the document thesis presents reflections with regard to methodological considerations in data collection process. A methodology is the systematic approach we used in process of finding answer our research question. Qualitative studies in form of semi-structured interviews is the main method we applied to answer the research question. The interviews were chosen as the primary method to get multiple perspectives, supported by observations. We also describe what characterize our methodological approach and include some reflections of the scientific tradition rooted in human science in phenomenology and hermeneutics based on Steinar Kvale interview guidelines in book “Doing Interviews’’ (Kvale, 2007).

A total of six face to face interviews were carried out: A convenience sample of four teachers was recruited from the school including the headmaster on the basis of willingness to participate. One technical bio farmer representing a community based social entrepreneurship was also interviewed in addition to his active participation in the project, and a group of four students from the class that was introduced to aquaponics were also willing to participate in a focus group interview. The semi-structured life world interviews with technician, teachers, headmaster and children gave us a unique opportunity to understand their daily life from their own perspective. The composition of the semi-structured interview guide questions (Appendix 1) indicates that the questions even if formulated in advance are not definite, but open to modification during the actual interview. The actual interviews resembled almost an open conversation focusing on description of the interviewees life-world in their own words. The subjects were encouraged to describe the actual situation as well as they can, what they experience and feel about the situation. Even though the structure of the interviews was a semi-structured the subject were asked about specific situation regarding aquaponics system not their general opinion about the system. In this study themes such as "opportunities'' and "challenges'' for aquaponics system implementation and incorporation into existing educational curriculum were in interview focus in life-word of the primary school educators. We as interviewers tried to gain actual description of interviewees life-world, understand the meaning of what was said and use our best abilities to appropriate and correct interpretation of it. We tried to pay special attention and register not only "what'', "why'' was said and understand the meaning of it, but also "how'' it was said by taking a role of an active listener and observant of non-verbal communication features and other body language gestures. Even though in general interviews interpretation on "meaning'' level may be difficult and prone to misinterpretations we tried to cover both the explicit description of what was said, the meaning of it and be vigilant to sometimes not always apparent implicit messages. During the whole course of interviews, we tried to be unprejudiced to new and sometimes unpredicted themes raised by the interviewees, instead of keeping rigid structure guide and our own presumptions, as Kvale stated it "the qualified naivete and a bracketing of presuppositions imply openness to new and unexpected phenomena'' (Kvale, 2007). The problem of ambiguity of interviewee's answers is a common occurrence during interview. Our role as interviewers and researchers is to clarify any ambiguous and contradictory statements from interviewees best to our ability. The process of collecting the qualitative interview data by different interviewers is a sensitive process as well. We are aware of the fact that different people even if they use the same interview guide may receive and produce different knowledge. This may be due to different levels of interviewers' sensibility, or knowledge of the interview subject as wells as individual focus and prioritizing of particular aspects. Finally, the idea of the qualitative interview despite the apparent power asymmetry is not merely data collection but it should be an enriching experience for both parts, a new insight into current situation (Kvale, 2007).

5.3. Methodology of text analysis.

5.3.1 Thematic analysis:

Since interviews were the primary technique for our data collection, we were thoughtful of the kind of the data analysis from the initial stages. The method of analysis chosen for the study was thematic analysis. We built our conceptual framework for the thematic analysis of the interviews mainly based upon the theories of Kvale's (1997, 2007) work on "Doing Interviews'' and that of Braun and Clarke (2006). Rigorous thematic approach can produce an insightful analysis that answers particular research questions; Braun and Clarke (2006) define thematic analysis as "a method for identifying, analyzing, and reporting patterns (themes) within data which minimally organizes and describes a data set in (rich) detail while going further to interpret various aspects of the research topic". Our thematic analysis seeks to provide a more detailed or nuanced account of a group of themes, within the data, but mostly relating to the specific areas of interest such as on identifying the challenges and opportunities of using aquaponics at school within the data. Braun and Clarke (2006) went further to identify a theme as one that "captures something important about the data in relation to the research question, and represents some level of patterned response or meaning within the data set". They explain that themes or patterns within data can be identified either in an inductive "bottom up" or a deductive "top down" approach; and also argue that using data collection questions (such as from an interview schedule) as the "themes" are the "worst examples of thematic analysis", because they are entirely deductive and fail to take account of emergent themes based on a process of induction (Braun and Clarke, 2006). Questions employed in our interviews were more open-ended to begin with, followed by some semi-structured questions while keeping key points relevant to our research questions. For this reason, our main categories and themes were identified from the data and therefore we were inclined towards an inductive approach, a process of coding the data without trying to fit it into a pre-existing coding frame, or the researcher's analytic preconceptions; which also according to Thomas (2003) primarily allows research findings to emerge from frequent, dominant or significant themes inherent in raw data, without restraints imposed by structured methodologies. Thomas (2003) identifies three main purposes for using an inductive approach as: A). To condense extensive and varied raw text data into a brief, summary format; B). To establish clear links between the research objectives and the summary findings derived from the raw data; and C). To develop a model or theory about the underlying structure of experiences or processes which are evident in the raw data. From these it can be said that the first two purposes were achieved in our work while the last would be possible subject to more studies before coming up with a generalized model or theory.

5.3.2. Rigor demonstration using thematic analysis.

A number of techniques and methods for analyzing and interpreting qualitative interviews exist and they vary significantly. For instance, Kvale (1996) describes five analytical methods that include A) meaning condensation, B) meaning categorization, C) narrative structuring, D) meaning interpretation, and E) generating meaning through ad hoc methods. In our study, all data collected through interviews with the informants were analyzed based on a three-stage procedure as also suggested by Creswell (2007) and Miles & Huberman (1984) while focusing on the "meaning" component of what was said. This followed the preparation of the data for analysis by transcribing, reducing the data into themes through a process of coding and representing the data. In addition, Braun and Clarke (2006) also argued that patterns are even more identified through a rigorous process of data familiarization, data coding, theme development and revision. We at first, familiarized ourselves with the data collected as audio recordings by listening to them a numbers of times while internalizing the information and transcribing it as accurately as we possibly would. Except for the focus group, all interviews were transcribed verbatim by us "the researchers". The transcribed interviews before the process of analysis were divided into 7 different coloured codes (Red-Challanges, Blue-Opportunities, Purple-Relevance/Importance, Yellow-Senses, Grey-Expectations, Magenta-Food literacy/Sustainability and Green-Stakeholders) to an appropriate text fragment in all transcribed interviews (Appendix 2). Coding can be understood as a process of breaking down the large text into smaller parts, a technique which helps examining and comparing the same themes of the different interviews. By coding it would be able to locate, distinguish and have better overview of different themes allocated in the transcribed interviews. In situation where interviewee's statements are very long meaning condensation strategy were used in order to condense the text into shorter version, with care of preserving the main sense of the text. The meaning condensed text could be later used to more extensive interpretation. In the meaning interpretation phase we as interviewers moved beyond to what was directly said by the interviewee in order to figure "structures and relations'' of the meaning. In the interpretation phase the analyzed text were quite often expanded and deepened by the interviewer meaning analyses. By the means of qualitative interview, we as researchers construct new knowledge in hermeneutical tradition in the process of interpretation of verbal and nonverbal communication. Knowledge is constructed by the intrapersonal interaction, exchange of views and understanding the meaning. The hermeneutical circle is a process of a text interpretation where meaning of the text is determined by determining the meaning of a different passages. The process of rereading of the different passages may again lead to change of the first meaning of the text, in return changing the text of different passages. In theory this is never-ending process, but in practice the process of text interpretation ends when a reasonable meaning has been achieved (Kvale, 2007).

5.3.3. Qualitative focus group interview.

In addition to the individual interviews, we carried out a qualitative focus group interview with school children at the School. The focus group interview was used as a suitable subjective research method to investigate pupils' behavior and motivations associated with using aquaponics. The key research factor behind this interview was to investigate what children think and feel about the aquaponics system and what if anything motivates them in learning about it. One of the criteria of choosing focus group interview was the young age of the children. The reason behind using focus group interview with teenagers was that this form of interviewing in our view would make them feel more comfortable and more enthusiastic to engage in a free and open discussion while being among their peers. A focus group interview method investigates and studies motivation among participants and the responses collected provide better understanding of the phenomenon. As mentioned under sampling, the particular focus group studied consisted of four teenagers aged 13-

15-year-old, sampled by voluntary participation from a mixed class of fifteen pupils that had been introduced to the aquaponics system. This method of investigation gives an opportunity to freely express everyone's attitudes and way of thinking, where conversation in lively peers' surroundings may bring some spontaneous and emotional opinions. In contrast to an individual face to face interview which may in some instances lead to building of tension between the interviewee and interviewer, focus group interview is perceived as being less tense for the participants (Kvale, 2007).

The role of interviewer was to moderate the flow of the conversation and direct the conversation in desired path with minimal intervention in the conversation flow. The task of the interview moderator was merely not asking every individual the same question, but support and facilitate an open discussion. An open discussion in focus group may lead sometimes to unexpected outcome making research more interesting. In the process of investigating children's motivation and engagement in aquaponics focus group interview gave an opportunity to collect interesting opinions, a situation where respondents did not have to choose from already pre-prepared responses. Group interaction helps brainstorming and building on each other's ideas. Nevertheless, the focus group responses may not reflect all individual opinions and some individuals may dominate the group, influencing responses. The main point of the focus group interview was not to achieve consensus about the particular issue but to present different point of view among the participants about aquaponics and its usefulness. Finally, because of its characteristics focus group interview material was more chaotic and data collected were difficult to transcribe and analyze (Kvale, 2007, p.72).

In the process of focus group interview transcription, we decided to use an intelligent verbatim style where all background noises, repetitions are omitted and grammatical mistakes corrected if necessary on the transcribed document. Even though the participants' social interaction is important by having potential influence on the study outcome we concluded that the intelligent verbatim style compared to strict verbatim style would be sufficient and adequate to fulfill the study needs. To facilitate the work with the transcribed version of the focus group interview timeslots were inserted next all questions a procedure similar to timeslots in individual interviews. In the transcribed version of the interview children as participants were denoted as "Participant''

(P) e.g. P1-P4 and the interviewer as "Moderator'' (M). It is much more complicated and time consuming to transcribe focus group interview because of the multiplayer characteristic of the method. The transcriber has to take into consideration not only what is said and how responses are formulated, but also who is saying particular part throughout the entire discussion. It can be a challenging issue due to the fact that it is very difficult to recognize individual voices on the audio recorder, especially in larger groups where people have tendency to interrupt and talk over each other (Liamputtong, 2011).

6. Theoretical framework.

We believe that it is important to establish some basis for this study on strong theoretical foundations rather than solely on educational practice. Our inquiries led us to the educational theories used in this section. These are aimed at helping in understanding how learners make meaning of what is learnt through the enablers such as communication and other tools availed to them. The section presents an integration of five major theories with synergies on the subject of learning that is meaningful to both the individual, that can benefit the society as well. They have been featured to help articulate how worthwhile knowledge can be acquired, retained and shared across the society taking the school platform as the point of departure.
These are:

- Lev Vygotsky's Zone of Proximal Development (ZPD) theory.
- John Dewey's concepts of pragmatism.
- David Kolb - Experiential Learning Theory (ELT)
- The Knowledge Triangle - the interaction between research, education and innovation.
- Problem Based Learning (PBL)

6.1. Zone of Proximal Development (ZPD) theory.

This section presents Lev Vygotsky's Zone of Proximal Development (ZPD) theoretical perspectives arguing that, it can enrich and enhance theorizing on the practical learning environment as presented in this research by the use of Aquaponics as an educational tool. Vygotsky's work can be considered timeless as it is more relevant in today's academic and social worlds unlike in his lifetime, when he produced it in the context of post-revolutionary Russia. Before his death in 1934 (at age 38), Lev Vygotsky had theorized at the general relationship between learning and development, and on very specific features of the relationship when children reach schooling age. Even though he recognized that the learning process predates school age, for purposes of this research, we acknowledge that presenting the entire learning process in the lived life of a child to adulthood from preschool time, is beyond the scope of this study. We therefore delimit ourselves to the learning that takes place at school age onwards herein referred to as "school learning". This kind of learning according to Vygotsky's is concerned with the assimilation of the fundamentals of scientific knowledge. In examining the dimensions of school learning, Vygotsky's introduced a concept he termed as "the Zone of Proximal Development (ZPD)" which he defined as:

"*The distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers"* (Vygotsky, 1978: 85).

In order to discover actual relations of the developmental process to learning capabilities, Vygotsky's argued that at least two developmental levels must be determined namely:

1. The actual developmental level; one that was initially solely associated with a child's mental functions and that is normally determined through tests. Here, it is assumed that only those things that children can do on their own are indicative of their mental abilities. This level defines functions that are considered matured, that is, the end products of development.
2. The zone of proximal development – the potential developmental, where for example; leading questions are given, or the child is shown how the problem is to be solved. The child then proceeds to solve it, or the teacher may initiate the solution, and the child completes it in collaboration with other children. This level defines those functions that have not yet matured but are in the process of maturation.

This two levels signify some continuity and transformation of the learning process in which case what could be considered currently as the zone of proximal development will turn out to be the actual developmental level in the future. To put it in Vygotsky's words

"...what a child can do with assistance today, she will be able to do by herself tomorrow" (Vygotsky, 1978: 87).

Being in agreement with Vygotsky's views on the ZPD, it was expected that the school children intended to be users of the school aquaponics system, fall into the two levels as identified above. The children were expected to be able to perform certain tasks on their own such as adding water to the system, filling grow media into the grow beds and other simple tasks with minimal instruction, and therefore they already possessed those abilities, whereas there were those functions that they could only perform under guidance from the teachers, and experts either individually or in groups, and in collaboration with one another, but they may not have mastered them on their own such as: technical details on assembling the siphon bell system for periodical draining of water from the grow bed to the sump tank, detection of nutrient deficiencies through plant leaf examination and the measuring and adjusting of the pH in the system once it fluctuates. It was hoped that after adequate guidance and collaboration, they would in future become the "knowledgeable other" capable of carrying out those practical functions individually. From Vygotsky's theories we anchored on the notion that:

"Children can imitate a variety of actions that go well beyond the limits of their own capabilities. Using imitation, children are capable of doing much more in collective activity or under the guidance of adults".

With this in our collective mind "We presumed that an aquaponics system for learning, set up in a school environment would create a zone of proximal development; in the process, the nature of learning in practice would awaken various developmental processes able to operate only with interaction with people in the children's environment and in cooperation with their peers. As Vygotsky argued:

"Once these processes are internalized, they become part of the child's independent developmental achievement" (Vygotsky, 1978: 90).

We hoped that, such a learning approach when properly organized could lead to a higher mental development necessary in developing a culturally organized human society. Figure 15 represents an illustration of the zones as would be depicted by Vygotsky.

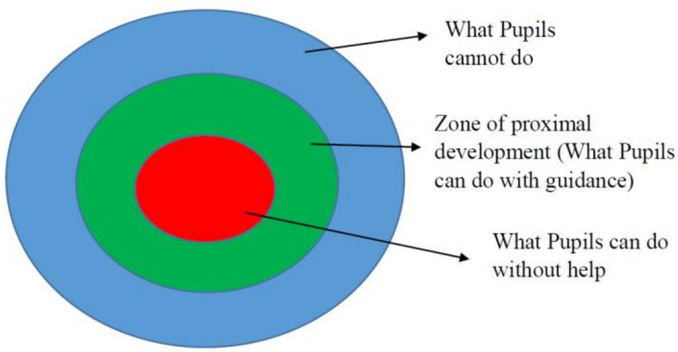


Figure 15. Zone of proximal development.

In the last two decades, the concept has been widely used or referred to in studies about teaching and learning in many subject-matter areas including: Information technologies (IT), computer-mediated communication and children's use of libraries (Cheong & Ah-Teck, 2015; McKechnie, 1997; Eady & Lockyer, 2013). Vygotsky's theory can provide teachers with some guidance on how to use technology in teaching and learning. Vygotsky argued that we learn by modelling and interacting with others and that social interactions can facilitate development of higher-order functions when they take place in cultural contexts (Vygotsky, 1978). Vygotsky further argued that students learn when they interact and communicate with other learners in a positive environment and that instruction is considered to be more effective when it is connected and relevant to the learner. Therefore, in an instruction and learning situation, such a concept to explain the relationship between the subject matter of instruction and its consequences for psychological development is needed. These makes for the explanation of how intellectual capabilities are developed. It is along this line of thought that Vygotsky reasoned on to come up with the concept of the Zone of Proximal Development (ZPD) presented above. The zone focuses on the relation between instruction and development which essentially is the difference between a learner's independent ability and what can be accomplished cognitively with guided support from others who are more knowledgeable. Vygotsky's (1978) came up with, and emphasized terms such as: “More Knowledgeable Others” and “Internalization” in which he positioned the knowledgeable ones such as advanced peers, adults and teachers at the periphery and learners such as students at the center; the learners connect their prior knowledge to what they experience, see, and hear to make meaning and take on to own what is learnt. It is during this process and through interactions, that the learner gradually moves from the center to the periphery through the ZPD to become more knowledgeable as also illustrated in Figure 5. In a contextual view of Vygotsky’s notion of ZPD; it means that teachers have an important role in facilitating a form of collaborative learning for the students (Doolittle, 1997).

6.1.1. Collaborative learning using aquaponics in the context of Vygotsky’s ZPD.

Collaborative learning can be an important learning strategy for educators to teach and to use at school. It can be understood as a situation in which two or more students work together to search for understanding or meaning, or to solve a problem. Collaboration is at the core of Vygotsky’s theory of learning. He believed in a natural social nature of learning reflected in group-based learning which consequently improve and enrich student knowledge by combining strengths, the sharing of responsibilities and learning from one another (Vygotsky's, 1978). In such a learning experience with minimal guidance by an educator, the students are able to work together towards a common goal and, in the process, depend on one another for their experiences and knowledge. Lave and Wenger (1991) in their contemporary interpretation of Vygotsky’s ZPD, present a more relevant theoretical view which can be applied to aquaponics in the theory of situated learning. They argue that learning, is most effective when co-constructed in the context in which it is to be applied implying that situated learning does favor collaborative learning activities that are carried out in authentic environments, with pedagogical strategies that model authentic, real-world tasks (Lave and Wenger, 1991).

6.2. John Dewey’s concepts of pragmatism.

In our theoretical considerations we have featured the various works of John Dewey in relation to education and its place in the life of an individual and society at large. Dewey is considered as one of the forefathers of pragmatism. Goldfarb (1998) described Dewey as: *“a contented classical American idealist with a philosophical and psychological orientation towards pragmatism”*. In “CIVILITY AND SUBVERSION- “The Intellectual in Democratic Society” (1998), He better presents Dewey as: *“an intellectual in action: one grappling with the eclipse of public life with the development of mass society; a populist professor, a scientist with anti-elitist views, a democrat who wrote opaquely, but for the popular audience”*. Dewey’s politics was considered to be idealistic and radical while his philosophy was realistic and practical (Goldfarb 1998). Dewey is well known to have made an American democratic contribution to modern academic philosophy by developing a special way of doing philosophy in public which informed public opinion, particularly in and through public education.

6.2.1. On the societal worthiness of an education.

Education can be looked as a means to addressing some of society’s problems. In his early works on “Democracy and education” Dewey pointed out that there is a difference in the social scope of purposes and social importance of problems. Dewey (1916) argued that, while there is wide range of possible material to select from, it is important that education be used as a criterion of social worth. In his own words:

> *“The scheme of a curriculum must take account of the adaptation of studies to the needs of the existing community life; it must select with the intention of improving the life we live in common so that the future shall be better than the past” (Dewey, 1916).*

Nowhere can the subject of education for sustainable food production be more relevant than in this context in today's world. Indeed, all human beings regardless of class, race or creed feed for sustenance of life. Having established the challenges associated with nutrition, health food and production in general, education for sustainability using the aquaponics tool, taken from Dewey’s perspective can be argued to carry such societal worthiness, or so we hope. Dewey explored deeply on how an educational curriculum must be planned. He came up with two categories that he named: essentials and refinements, which are to be prioritized as first and second respectively. To these, he classified the things which are socially most fundamental, things that have to do with experiences in which the widest groups share-the essentials, while the other things which represent the needs of specialized groups and technical pursuits as secondary or refinements. Dewey reinforced the saying that *"education must first be human and only after that professional"*. He went on to propose a curriculum which acknowledges social responsibilities of an education, one that presents situations where problems are relevant to the problems of living together, and where observation and information are calculated to develop social insight and interest (Dewey 1916, 157).

In his later works on the "the Quest for Certainty" published in 1930, Dewey suggested that active science play a key role in bringing about meaningful change in society. He is quoted to have said in one of his lectures that:

> *"Science advances by adopting the instruments and doings of directed practice, and the knowledge thus gained becomes a means of the development of arts which bring nature still further into actual and potential service of human purposes and valuations" (Dewey, 1929, 83).*

With this views forming a key pillar for our theoretical framework, we hope that readers can understand how we envision practical aquaponics to facilitate learning and therefore foster meaningful acquisition of knowledge among the pupils.

In Experience and education, Dewey (2007) argued that when education is based upon experience, and educative experience is seen to be a social process; the teacher loses the position of being an external boss or dictator but takes on being a leader of group activities. This eliminates the possibility of forcing activities of the young into channels which express the teacher's purpose rather than that of the pupils. Dewey advocated for the educator to arrange for the kind of experiences which do not repel the students, but rather engage their activities; selecting the kind of present experiences that live fruitfully and creatively in subsequent experiences. This makes the experiences become more than immediately enjoyable, since they promote having desirable future experiences (Dewey, 2007). He went on to suggest an appropriate way to teach saying:

"*The way is, first, for the teacher to be intelligently aware of the capacities, needs, and past experiences of those under instruction, and, secondly, to allow the suggestion made to develop into a plan and project by means of further suggestions contributed and organized into a whole by the members of the group"* (Dewey, 2007).

From these, we get the sense that the essential plan is to be based on co-operation between the learners and the educators; that the teacher's suggestions are not fixed dictations but a starting point to be developed into actionable plans through contributions from the experiences of all those engaged in the learning process. In this exchange, it would follow that the intended purpose of a project can grow and take shape through the process of social intelligence. From Dewey's other works on Democracy and education (1916), we get the notion that the human species continue to exist as one of complex life forms, better adapted to utilize the obstacles against which they have struggled successfully to come into being and as a feature of adaptation, Dewey placed education, as the means to a social continuity of life for humans that encompass the recreation of beliefs, ideals, hopes, happiness, misery, and practices (Dewey, 1916).

Dewey presented detailed philosophical views on what meaningful education should constitute and covered several aspects such as the mode of delivery in teaching, the environment in which knowledge was thus disseminated and created and the content or what he referred to as "the subject matter" among many. For instance, on the topic of "The Nature of Subject Matter", he observed that; "subject matter, or data, and ideas have to have their worth tested experimentally; that in themselves are tentative and provisional". To Dewey, these subject matter of education consisted primarily of the meanings which supplied content to existing social life. He went on to suggest that

"There is need of special selection, formulation, and organization in order that they may be adequately transmitted to the new generation" (Dewey, 1916).

It is important to have an understanding that school education takes place in a setting that enables two key actors to partake in the knowledge exchange namely: the educator and the leaner. Dewey argued that:

"The educator's part in the enterprise of education is to furnish the environment which stimulates responses and directs the learner's course …and all that the educator can do is modify stimuli so that response will as surely as possible result in the formation of desirable intellectual and emotional dispositions" (Dewey, 1916).

These argument brings us to the notion of knowledge distinction between the educator and the learner. According to Dewey (1916) the assumption is that the educator is more knowledgeable or at least needs to know both subject matter and the characteristic needs and capacities of his/her students. The challenge of teaching then becomes, keeping the experience of the student moving in the direction of what the educator knows. This is very much in agreement with Lev Vygotsky's notion of the "zone of proximal development" wherein the educator is considered as the knowledgeable person that is on the periphery, with the learner being at the center who then expands in knowledge and capabilities over time after learning to become the knowledgeable other. In this way, Dewey was categorical in showing a clear distinction between the learner and the educator. From his statement:

"The subject matter of the learner is not, therefore, it cannot be, identical with the formulated, the crystallized, and systematized subject matter of the adult; the material as found in books and in works of art, etc" (Dewey, 1916).

Dewey stressed on the need for having adequate knowledge on the side of the educator who serves as a guide and facilitator of the learning process, perhaps to guarantee true knowledge to the learner. On the educator, he argued that knowledge of subject matter ought to be significant and go beyond the present knowledge of pupils. That the instructor needs to have the subject matter at his/her fingers' ends; his/her attention being upon the attitude and response of the pupil. For these, and for the teacher to be considered learned, subject matter ought to be extensive, accurately defined, and logically interrelated so as to be able to supply definite standards to the pupils. In this context therefore, it is to be expected that the teachers must get themselves well prepared in content and with a well-reasoned level of understanding of the workings of the aquaponics system. From this basis, prior or updated knowledge of aquaponics is to be considered an essential competency to the teachers, which makes him/her know in advance the things which are new to the student thereby placing the teacher in a position of advantage. Dewey also championed for the need for organized and standardized guides for instruction as covered in educational curriculums. However, his emphasis was on the meanings the material for school studies carried on social life. These he argued, can help educators to avoid haphazard efforts through provision of the essential ingredients of a desired culture to be perpetuated in an organized form.

6.2.2. The role of activities and physical engagements in the learning process.

Dewey placed actions in physical form highly in the attainment of knowledge, also emphasizing the importance of interest on the part of the learner. In his lectures on interest and discipline, he stated that:

> *"The problem of instruction is that of finding material which will engage a person in specific activities having an aim or purpose of moment or interest to him, and dealing with things not as gymnastic appliances but as conditions for the attainment of ends" (Dewey, 1916, 109).*

Viewed in the above context, aquaponics with its living components such as the fish, the plants and worms can be presumed to have an "appealing draw" to the pupils. It is expected that the living things will spark new interest where it may not have been existent. The living things need care and maintenance to thrive, this is likely to prompt direct engagement by the students in activities such as feeding, pruning etc. if coordinated and led well by the teachers. Dewey argued that:

> *"The knowledge which comes first to persons, and that remains most deeply ingrained, is knowledge of how to do; how to walk, talk, read, write, skate, ride a bicycle, manage a machine, calculate, drive a horse, sell goods, manage people, and so on indefinitely" (Dewey, 1916)*

The list puts emphasis on the notion, that indeed for knowledge to be truly impactful and have a lasting effect on individuals, some form of activity is necessary. This can especially be relevant in the case of food production where the pupils beyond learning in theory, get to produce the actual food that they can use from the aquaponics system. Dewey stressed for the need to recognize that primary or initial subject matter always exists as matter of an active doing, involving the use of the body and the handling of material, emphasizing that:

"Having to do with things in an intelligent way issues in acquaintance or familiarity, and that the things we are best acquainted with are the things we put to frequent use"

This presents the aspect of exposure to the substance or physical material, and in most cases if it is a living thing, it will make us anticipate how it will act and react thereby making us ready for the familiar thing. A parallel would be drawn in aquaponics, where for instance in crop leaf analysis; the pupils can see themselves what changes occur to the plants in case of nutrient deficiencies. By taking certain steps to correct it, they become more aware or familiar of the causes, effects and what to look out for, which may instill confidence and ease as they are not likely to be surprised by some occurrences at a later time. It can often be the case that the things with which we are not accustomed to deal with appear strange and abstract. These can be avoided and therefore be beneficial to those who would like to work with similar food production in their afterschool lives. We support the argument therefore, that meaningful knowledge is that which follows action; and as Dewey himself noted:

"Knowledge which is mainly second-hand, other men's knowledge, tends to become merely verbal and lacking in meaning".

Even though Dewey acknowledged that information is clothed in words and that communication takes place through words, he was critical of the fact that, if what is communicated cannot be organized into an existing experience of the learner, then it becomes mere words that is basically pure sense-stimuli (Dewey 1916, 64). He presented a technical definition of education that focus on action: "It is that reconstruction or reorganization of experience which adds to the meaning of experience, and which increases ability to direct the course of subsequent experience". Here, we note that increased meaning is associated with increased perception of the connections and continuities of the activities in which one gets engaged. Dewey gave the common example of a child who reaches for a bright light and gets burned. In his words:

"Henceforth he (the child) knows that a certain act of touching in connection with a certain act of vision (and vice-versa) means heat and pain; or, a certain light means a source of heat".

The lesson we can learn from such an activity is that, an activity bringing education or instruction with it makes one aware of some of the connections which would otherwise have been imperceptible. Dewey also acknowledged the use of language as an educational resource and stressed that it should not lessen; but that its use should be more vital and fruitful by having its normal connection with shared activities. "That education is not an affair of "telling" and being told, but an active and constructive process". For education to be enacted into practice, it is required that the school environment be equipped with agencies for doing, with tools and physical materials. The methods of instruction and administration should also be modified to allow and to secure direct and continuous occupations with things (Dewey 1916, 34). This is very much in line with what we hoped the practical aquaponics unit at the school, would help achieve for the users.

6.2.3. Social-Learning from others in groups and individual tasks of common undertaking.

Dewey (1916) argued that there is an interconnectedness in the learning process in a group regardless of whether tasks are carried out individually or as a group. According to Dewey, the established active connections with others makes it impossible to draw sharp distinctions in our experiences from those of others. In support of this argument, Dewey is noted to have said that:

"The things which others communicate to us as the consequences of their particular share in the enterprise blend at once into the experience resulting from our own special doings"

However, Dewey cautioned on excessive reliance on others to learn, arguing that the information from others should serve best to steer an inquisitive mind to investigate further, and through some form of individuated action establish and confirm that which we learn from others. We take the warning that:

"Excessive reliance upon others for data (whether got from reading or listening) is to be depreciated. Most objectionable of all is the probability that others, the book or the teacher, will supply solutions ready-made, instead of giving material that the student has to adapt and apply to the question in hand for himself" (Dewey 1916,128).

6.3. David Kolb's Experiential Learning Theory (ELT).

David Kolb is both philosopher and psychologist best known for his research in the field of experiential learning and different learning styles. In 1980 he established Experience Based Learning System (EBLS) an institution which investigates experiential learning. He is also an author of several experiential learning exercises and assessing tools such as e.g. Kolb Learning Style Inventory 4.0. Kolb in his long life as a researcher was inspired among other great experience theorist by work of Dewey, Lewin, Piaget, Vygotsky and James. In contrary, Kolb did not agree with the generally well accepted in the first half of the 20^{th} century behavioral concept of learning, where human behaviors were perceived as stimuli-response relation of an experience, disregarding to a large extent any subjective and conscious aspects of an experience in learning processes of individuals. David Kolb sees learning as a social process supported by one's individual experiences, an idea that is not aligned what is commonly understood by the word ''teaching'' even today. In his view classroom and lectures are not the only way where knowledge can be obtained by learners, but equally important are the experiences gained elsewhere e.g. in family, workplace or in local communities. In Kolb opinion teaching doesn't have to be associated with traditional concepts of lessons, grades and calendar schedules etc. but instead with personal skills, competences and useful knowledge which could be applied by an individual in the future, either in private life or professional carrier (Kolb, 2015).

David Kolb characterizes "experiential learning'' and knowledge acquired as something human beings gain throughout life experiences, a concepts opposing traditional understanding of school lectures. Kolb's understanding of experiential learning underlines predominant role of experience as a major source of knowledge in learning process, being of greater importance than objective knowledge and thinking. He himself formulated main focus in experiential learning where: "emphasis is often on direct sense experience and in context action as the primary source of learning, often down-playing a role for thinking, analysis, and academic knowledge'' (Kolb, 2015). This kind of approach is approved by some educational institutions and very common in Scandinavian countries e.g. Denmark, where many educational institutions offer experiential learning in form of internship, group work and problem based learning approach running alongside the traditional lecturing. One of the examples confirming the fact that people do learn from the experience is the fact that the ''experience knowledge'' could be verified and the results used as credit for higher education admission, such as so-called quota 2 applications in Denmark solely based on candidate experience qualifications.

In ELT David Kolb (1984) presented a theoretical standpoint of different and unique to every human learning processes. Kolb presents a holistic approach in the process of knowledge acquiring with the role of experience as a supportive and facilitating factor. A holistic approach because the ELT should not be perceived as an alternative to other behavioral or cognitive theories, but as a theory trying to combine role of experience, cognition and behavior in learning processes. The idea behind the ELT is to generate theory, which on the other hand will help to find answer to a question of how experience could be transformed into reliable and objective knowledge, at the same time bearing in mind that objective knowledge does not necessary derives from an experience (Kolb, 1984).

Kolb's Experiential Learning Theory (ELT) model share some similarities and it was inspired by previous work researched in the field of experiential learning: Lewinian model of action research and laboratory training, John Dewey experiential learning model, Piaget's model of learning with emphasis on cognitive development in learning processes (Kolb, 1984, pp. 21-25) (Piaget, 1964), and the concept was influenced by William James philosophy of radical empiricism (Kolb, 2009 pp. XVII-XVIII). In all these theories learning is not viewed as a linear process, bus as an experience cycle of interaction between human and the environment.

David Kolb created ELT model also called a learning cycle (Figure 16) based on his understanding of how knowledge is created: "knowledge is created through the transformation of experience.

Knowledge results from the combination of grasping and transforming experience" (Kolb, 1984, pp. 41). The grasping experience in the model is called ''perception continuum'' and transforming experience is called "processing continuum''. The opposite poles of the learning modes in perception continuum are related with each other - Concrete Experience (CE) and Abstract Conceptualization (AC) and in processing continuum - Reflective Observation (RO) and Active Experimentation (AE). The process of creating knowledge in the model involves all four learning modes, as shown in the form cycle, where individuals have chance to experience phenomenon, reflect on what they saw, think and act by being motivated by the experience. New experiences and occurrences to which learner is exposed to are foundation and incentive to reflect upon it. The reflections are further conceptualized by processes of critical thinking, which in turn could lead to process of a new action taking. It is also important to keep in mind that not only Concrete Experience mode refers to an experience. All four learning modes (CE, RO, AC and AE) are part of an experience in learning processes (Kolb, 1984).

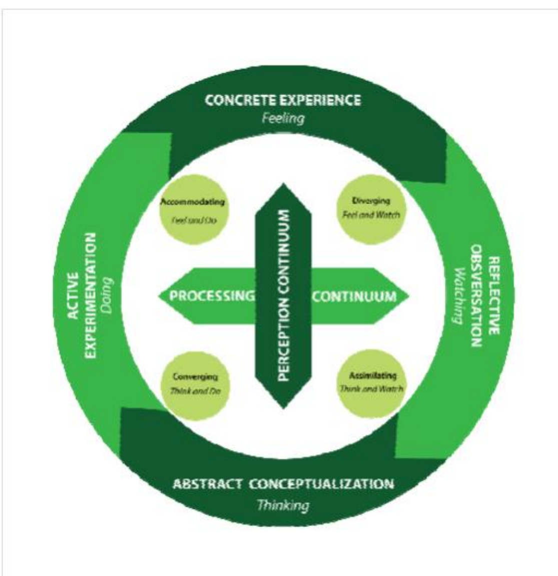


Figure 16. Kolb's Learning Theory (1974) source: (University of Toronto, 2017).

The ELT cycle is not a static, but dynamic process like a spiral, where knowledge gained by an experience builds up and moves to another, more advanced and nuanced level "When a concrete experience is enriched by reflection, given meaning by thinking, and transformed by action, the new experience created becomes richer, broader, and deeper. Further iterations of the cycle continue the exploration and transfer to experiences in other contexts'' (Kolb, 2009).

The role of teachers in this perspective in teaching aquaponics could be to set higher level learning goals in time, by building on students growing knowledge in the study field. The knowledge gained by the students could be also transferred with the teacher's assistance into other similar context or subject e.g. by the use of multidisciplinary application of aquaponics in different subjects from biology, math, science and many other.

In summary, David Kolb's ELT cycle model is a holistic representation of human learning processes of how people accommodate knowledge and further develop. The model central focus is on "experience'' as a key factor in learning processes and differentiates from cognitive learning theory which states that learning processes could be explained by mental processes and behavioral learning theory which do not reflect on neither subjective experience nor social and cultural predispositions of individuals but on stimulus-response relation.

6.3.1. Experiential Learning Theory in practice.

In this chapter we will try to describe practical implication of theoretical framework of Kolb's Experiential Learning Theory in real life situation. It can be done by presenting practical usage of aquaponics technology in teaching primary school children in Copenhagen, Denmark about issues concerning nature, sustainability, ecology. The example of experiential learning could regard to aquaponic system set up in Blågård school among 8-9 grade school children. During the process of the system set up, children had chance to learn about aquaponics not only form instructor lectures, but also by observation and direct interaction with the actual aquaponic environment, in contrast to theoretical materials. This interaction may result in very important learning experiences and help children in understanding real life environment. Following the particular example in the context of four learning modes by Kolb (1984), in the stage of "concrete experience" student senses the physical experience of seeing and touching aquaponic facilities and plants. In this stage students can also be asked to perform practical exercise e.g.: drawing all components of the closed-loop aquaponics system. By observation students have an opportunity to "reflect'' on how different aquaponic components are interrelated and dependent of each other and draw in on the paper. Children develop a skill of how the system is constructed and think about ways of how it's connected or find ways for the technological improvements "abstract conceptualization'', as well as visualize different scenarios of what would happen if one of the components slightly changes its characteristics. In the last stage "active experimentation'' children can take an active part in a number of practical hand-on activities from fish feeding, plant investigation to ph measurement and even building their own small scale aquaponics system. Below (Figure 17) are pictures of school children during the system set up, mirroring Kolb's Experiential Learning Theory cycle.

Figure 17. David Kolb's Experiential Learning Theory in practice.

6.3.2. David Kolb's learning styles.

Kolb's ELT model as early mentioned consists of four different learning modes (CE, RO, AC, and AE. Those learning modes alone or in combination with each other create diverse learning styles, which in turn are individual and unique characteristics for every person based on personal preferences and predispositions. However, it is worth adding that the learning styles are not fixed and unchangeable features, but instead modifiable – a subject to dynamic processes as a result of the interaction between a person and surrounding environment "This dynamic state arises from an individual's preferential resolution of the dual dialectics of experiencing-conceptualizing and acting-reflecting'' (Kolb, 2009). The model classifies nine different learning styles: Experiencing (CE), Reflecting (RO), Thinking (AC), and Acting (AE) deriving directly from the four learning modes, and four other learning styles as a results of combinations of two modes, one from perception continuum'' and one from ''processing continuum'': Diverging (CE and RO), Assimilating (AC and RO), Converging (AC and AE) and Accommodating (CE and AE). The ninth "balancing'' learning style is the most versatile learning style combining all four modes (Kolb, 2009). Below are Kolb's descriptions of each of the nine learning styles underlying individual learning style main characteristics and balancing neighboring one.

As an example, students with the Experiencing learning style (CE) accentuate *"feeling''* as central characteristic while balancing adjacent features of *"acting''* (AE) and *"reflecting''*. Students with these abilities feel comfortable among peers *"Their greatest strengths reside in their ability to deeply involve themselves in concrete experiences while being equally comfortable in the outer world of action and the inner world of reflection'' (Kolb, 2009).* They are vigilant, active and gain knowledge by observing the surroundings. They are particularly into practical activities like field trips and group work. In contrast they are least adept in AC, therefore persons with this learning style can lack theoretical competences and be sometimes disorganized. The strength of Reflecting learning style (RO) lies in the *"capacity for deep reflection informed by the ability to be both feeling oriented and conceptual'' (Kolb, 2009)*. Students with this learning style have the ability to combine creative ideas with logical thinking. Student who prefer this learning style tend to ask questions "why'' things are the way they are and "what'' makes them to be like that. They learn by interaction and discussion with others, as well as gaining knowledge through reading, which allows better understanding of the specific concepts. Because of their low ability of Active experimentation (AE), they rarely put their plans or thoughts into action. Thinking learning style students (AC) as the name suggests are deep thinkers *"who are able to inductively develop a particular concept or idea and deductively evaluate its validity and practicality by testing it in the real world" (Kolb, 2009).* Student are able to reflect about their experiences and take action upon it. They feel most comfortable working with theoretical concepts that can be applied in other situations. Because this learning style put the least emphasis on feelings, students tend to be rational and sometimes dispassionate. They learn best individually in well-organized learning environment. Acting learning style students (AE) *“combine the ability to find solutions to questions or problems based on their technical analysis with attention to the needs of people and sources of information in concrete situations’’ (Kolb, 2009).* Students with natural inclination to this learning style thrive by taking action in practical world by combining abilities of logical thinking and feelings. Because thorough reflection is not their strongest point, hasty decision of the “right’’ solution could be taken prematurely into action. They learn best by taking a role in real-life project and field trips (Kolb, 2009).

The section below further describes Kolb’s (2009) learning styles created by merging of neighboring learning modes. Diverging learning style combines CE and RO learning modes. Students having this learning preference are rather observant than active participants. They feel best in learning situations which demand creativity and engagement of feeling, for example in brainstorming sessions. *“They are imaginative and sensitive to feelings, have broad cultural interests, and like to gather information” (Kolb, 2009).* Therefore, they work best in groups and appreciate attention and personal feedback. Assimilating learning style students (AC and RO) learn by accommodating a number of information and by transforming it into short logical form. In general, it may be of more importance “*that a theory has elegance and logical soundness than practical value’’ (Kolb, 2009).* Students with this learning style would rather study individually in order to have more time to think thoroughly. They learn best by reading, during lectures and by means of more formal education. Converging learning style students (AC and AE) are eager to solve problems by taking an action which is based on thorough logical considerations. They would rather immerse themselves and deal with technically and logically related problems than interpersonal issues *“because they place less emphasis on feeling and reflection in their learning style, they can be uncomfortable in ambiguous situations and interpersonal issues’’ (Kolb, 2009).* Accommodating learning style students (CE and AE) prefer taking part in hands on activities and feel very comfortable in dealing with unknown situations. They quite often act upon their intuition rather than analytical knowledge. In the situation of information collection, they often rely on their peers and other people than the official sources of information. Students with this learning ability tend not to reflect and thoroughly think before acting and may seems to be disorganized. Finally, students with “balancing’’ learning style have acquired ability to use all four learning modes. Depending on the task they are faced to deal with, they are able to change the learning style. They are very often creative, but at the same time indecisive, but in a team work they can adjust to feel a gap of a missing learning mode needed to complete problem solving. This ability *''allows them to see many different perspectives on issues and bridge differences between people with different styles''* (Kolb, 2009).

6.3.3. Why is it important for teachers to know students learning styles?

School teachers should have knowledge about the differences in learning styles and the fact that students are all individuals and learn differently. Nevertheless, educators should always keep in mind that students have their natural abilities and preferences in the way they absorb, understand and preserve the knowledge. In the example of teaching about aquaponics some students would probably prefer read and listen about it while others would like to physically experience it with hands-on activities. People learning styles are different and unique for every individual, shaped by cognitive, emotional and social factors. Therefore, it is important for educators to understand those differences in order to use best practices tailored to each individual and nuance learning practices to effectively reach the biggest learning effectiveness.

It is the lecturers' duty to design teaching material in a matter that fit demand for effective teaching and find balance between those four learning modes. Appropriate time and space for "experiencing" will make it possible to engage, sense and fully feel the actual experience by a student. This experiencing can be inhibited by too sudden transition into conceptual "thinking" mode. "Reflecting" and thinking" both also need right time and space to be effective. Silence and peace of mind help in processes of deep reflection and helps in the course of generating new concepts and ideas. On the other hand, extensive time devoted for both "reflecting" and "thinking" modes may prevent taking "active" role if needed, but at the same time in the contrary hasty decision and acting without a methodical consideration may results in experiment or project failure. Despite the natural learning predisposition and preferences, according to Kolb (2009) "Overall learning effectiveness is improved when individuals are highly skilled in engaging all four modes of the learning cycle" (Kolb, 2009 p.318) if adequately balanced by the teachers.

6.4. Knowledge Triangle - the interaction between research, education and innovation.

The theory of Knowledge Triangle (KT), refers to concepts of research, education and innovation and attempt to better interconnect these elements in the society. According to OECD (2016) there is a need for a conceptual tool for close cooperation between research, innovation and education institutions, a framework "that stresses the need for an integrated approach towards research, innovation and education policy- a tool helping for better understanding, knowledge-building as a multifactorial and systemic process, depending on the interaction between education, research and innovation" (OECD, 2016). Each of three elements of the Knowledge Triangle (Figure 18) should be closely bond and influence each other. "Interaction of education and research activities results in postgraduate formation, scientific research and researchers' mobility programmes. Linkages between research and innovation can be characterized as knowledge transfer activities like public-private innovation partnerships; commercialization of publicly-funded research, university-industry research contracts; intellectual property rights; university spin-offs; knowledge transfer offices; business incubators; open science policies. The relationship between education and innovation can lead to the development of entrepreneurial attitudes of students and the development of key competences demanded by the productive sector" (OECD, 2016a).

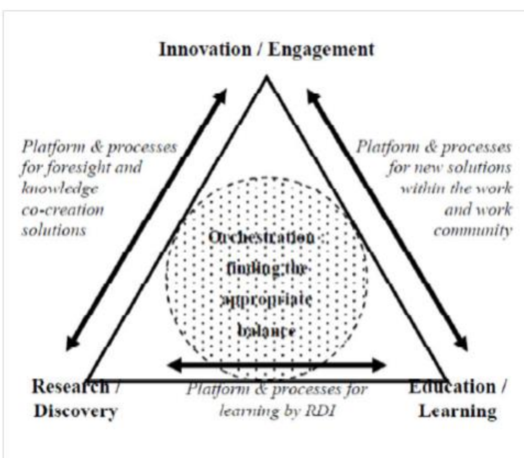


Figure 18 Knowledge Triangle model. Source: (OECD, 2016a).

European leaders have also realized the need for close bonds between innovation, research and education. The European Commission launched the biggest EU 7 years (2014 – 2020) framework programme for research and innovation called Horizon 2020. This programme is predominantly economically driven with an aim to secure Europe's future market competitiveness, increase economic growth and create work places. A close collaboration between innovation and research organization and scientific expertise provided by the educational institution is thought add to Europe's economic leadership and deal with future social challenges (European Commission, 2017). Additionally, EU leaders tried to promote KT elements in the establishment of independent organization named European

Institute of Innovation and Technology (EIT) in 2008 as an integral part of Horizon 2020. The purpose of the organization is to encourage better link between innovation, research and higher education institutions and facilitate the process of knowledge exchange within institutions. The main focus of the organization is on promotion of innovation and entrepreneurship across Europe as well as designing friendly platform for an active cooperation between research labs, educational bodies and private businesses, with hope to create innovative products and services (EIT, 2017).

The word "interaction'' is a key in understanding the KT model. What symbolize the model is the interaction among different actors across of the three domains and creating conditions for smooth knowledge transition among them. In KT model knowledge transition process is no-linear, this gives an opportunity for continuous updates and feedback among various stakeholders. The report prepared by Jávorka & Giarracca (2012) describes number of European educational institutions engagement in interaction between education, research and innovation organizations. The document is a practical guide illustrating number of different actions taken by the institutions in the process of knowledge sharing and problem solving practices encountered during the process (Jávorka & Giarracca 2012). The KT model should be perceived for the thesis write up purposes as an overall frame, a reminder of need for a close connection between education, research and innovation. This thesis project main emphasis is on the role of education institutions in the knowledge triangle. Primary school education as a stage for performing aquaponics experiment, with higher education institution such as AAU and private entrepreneur providing knowledge and research support and possible connection to the businesses. From the point of view of the educational institutions building new relationships and by that creating and sharing knowledge are some of the essential issues nowadays. It should be noted that the rigid definition of the three KT elements should not be too restricting. The word "innovation'' should be understood here not only as technological innovation of aquaponics system, but also as an innovation in changing organizational structure of primary school teaching, possibly adding creativity element of aquaponics into existing primary schools' educational curriculum. Innovation refers also to the teachers and their approach and degree of engagement in teaching aquaponics, willingness in the process continuation as well as interaction with other relevant actors.

6.5. Problem Based Learning (PBL).

In considering the mode of teaching that could be optimal for school children, it becomes necessary to understand the goals of instruction and the anticipated learning outcomes. Some of the desired cognitive outcomes that have been researched include: long-term retention of content, improvement in problem-solving and collaboration skills (Walker & Leary, 2009). These studies have led to approaches such as Problem Based Learning (PBL), emerging as best aligned to preparing students for deeper learning, higher-level thinking, and intra/interpersonal skills (Condliffe et al., 2016). In some cases, PBL has been found to provide an effective model for whole-school reforms (Cross, 2004; Newmann & Wehlage, 1995). Several studies have shown that well-designed project-based learning (PBL) approaches have been shown to result in deeper learning, engaged and self-directed learners. PBL has also been proven to increase retention of content and improve students' attitudes towards learning, among other benefits (Barron & Darling-Hammond, 2008). In his review of research on project-based learning, Thomas (2000) defined PBL as: "involving projects that are complex tasks, which typically results in a realistic product, event, or presentation, which is central to the curriculum, and which is organized around a driving question that leads to central principles or concepts of a discipline. PBL is student driven and constructive, involving inquiry, investigation, knowledge building, and resolution. PBL students are responsible for making choices and designing and managing their work, and they experience gains in factual learning that are equivalent or superior to those experienced by students engaged in traditional learning". It is important to note that in a PBL situation, teachers only serve as coaches and facilitators of inquiry and reflection while students usually, but not always work in pairs or groups and are in control (Thomas, 2000). Aquaponics system set up as a single project in a school learning environment in this research work has been treated as one such PBL project from our perspective as the researcher's in the knowledge triangle and also from the teacher-pupil's collaboration. We view the aquaponics system as a tool that could facilitate the kind of learning that relates directly to the world the kids live in; a world of food production and consumption. This in a way gives an extension of what is learnt beyond the classroom walls. The students can gather around the system that enables them to establish a real world ecological connection and this can get them to be more engaged when learning. While there is a certain freedom of engagement during lessons, collaboration can be structurally arranged in such as a way that core learning goals and standards are still maintained. The students are then challenged and provided with unique opportunities that helps them practice critical thinking, collaboration, communication, and creativity (Barron & Darling-Hammond, 2008). In that way the student driven environment within the classroom can be optimized for teamwork. For instance, after carrying some practical tasks as assigned or guided by the educators, students can give a presentation to their classmates on a key aspect from the system. This would be in the form of data collected such as amount of fish feed given per day or the weight measurement of produce after a given period or at harvest. Such engagements can get them to be more invested in their learning thus empowering them to work independently and collaboratively. While that is accomplished some form of assessment can also be embedded throughout the project and suitable tools for measuring student understanding and knowledge from the beginning to the end of a project employed, such as using questionnaires or carrying out individual or group interviews. This research work presents a practical aquaponics system set up within a school environment as learning and teaching tool with a range of teaching and learning strategies that are based on theories of learning that can allow educators to provide a range of experiences to their students.

7. Results and analysis.

This section of the paper includes analysis of the qualitative empirical data gained from the interviews conducted with teachers, headmaster, technician and the school children. The analyzed text which was initially divided into seven different codes subsequently forms diverse themes that summarize and give meaning to our data. In the process of analysis, we tried to identify the key ideas expressed in each theme underline the consistencies, differences as well as any contradictions that might have occurred. We also tried to establish connections between different themes in the process of explaining our findings to form coherence. It will further form basis for our interpretation of meaning and base for additional discussion and suggestions. The overall purpose of the text analysis is to find best possible answer to our research question.

7.1. Challenges.

7.1.1. Technical challenges associated with the aquaponics.

Technical issues and proper design of an aquaponics system are important when considering implementation of such a system in a given school. In order to have better picture of the most suitable aquaponics system, its design, size and other system characteristics which fits best to the school needs and wants discussion with Lasse who is an aquaponics enthusiast and technician took place in Copenhagen. There is number of challenges that may occur and which may be taken into consideration when setting up the most appropriate system.

Lasse was asked about the most important system specifics, requirements and cost estimates to power supply, water pump and other vital parameters that have to be taken into consideration to make the system work. Lasse mentioned the most important specifics, elements of the system and its cost:

''We need the two containers, at least two maybe three or four for the fish tank and the beds and it is nice to have it transparent so that you can see it, just looking at the side of the system however it can create some difficulties with algae bloom. You need to place the system right; you don't want the aquarium exposed to sunlight'' (Lasse, 03:58-08:49).

What can add to the cost of a unit is not only the number of the containers for the fish and grow beds for the plants, but also the material from which the containers are made of. The simplest and least expensive system may consist of minimum two containers, one for the fish and another for the plants. More pleasing for the eye and more esthetically attractive for the users of the system are the transparent containers, or glass aquarium where children and teachers who are going use it can see the fish and plants through. The challenge associated with such a solution is not only the higher cost of such a solution, but also a challenge with the appropriate placement of the aquaponics system in the classroom. Transparent containers should be protected from the direct exposure to the sunlight in order to avoid formation of algae on the surface of the containers and therefore placed in the shaded part of a classroom. In situation where the classroom is too dark without or very limited access to the natural light, artificial lightning could be an option. But challenge associated with such a solution is potential higher cost of electricity and possible errors in case of disrupted energy supply:

"You can also supply with either supplemental light or pure artificial light, however it adds a lot of cost to the system and it also takes electricity. It also makes it more prone to errors because you would probably want to have it somewhere where you had some light but still keeping your cost down'' (Lasse, 18:41).

Apart from the fish and grow bed containers and potential lightning expenses, there are also some individual components that can add to the overall cost of the whole system:

"A pump that moves up the water and the bell siphon consisting of four-five different components are the two most expensive things''(Lasse, 03:58-08:49).

When asked about system specifics in relation to the water pump, Lasse answered that the most suitable water pump should be able to move the water at least one and a half time of the fish tank volume per hour:

"So say we have 100 liters of water container then you need a pump that can pump between 150 to 200 liters per hour. And it is important in the design consideration to see the height of the lift that the pump needs to take because pumps has a head'' (Lasse, 11.26-12:14).

The plants in the grow bed and more precisely plants roots are not meant to be constantly immersed in the water. In the ideal situation the grow bed should be emptied (with the help of bell siphon) from water at least 1-1,5 time per hour. During the draining process the water for a grow bed drains completely to a sump container allowing very efficient delivery of oxygen rich air to the plant roots and beneficial bacteria which are living on the gravel stones. During the "flood'' part of the cycle incoming water in a grow bed distributes moisture and nutrient to the plants roots. Therefore, in order to have well-nourished and healthy plants it is important to have an appropriate water pump with efficiency to pump the water in the system at least 1-1,5 times in an hour.

Sustainability issues of the aquaponics system are crucial and it is important that the system have a minimal impact on the environment and resources needed. But it seems that in some circumstances the power consumption of the aquaponics system may question the so called ‘’green’’ method of vegetable production. When confronted with a question of having aquaponics system outside the classroom e.g. on the roof top and by that probably cut some cost on power supply by having access to natural sunlight and aeration Lasse replied:

“But depends on how you make it if you can have the systems outside but you will have a lot of other interferences in the system. Which I think will also disturb the explanation value of the system’’ (Lasse, 21.40 - 22.02).

He also pointed out another element that can add to the overall cost of the system:

“it is mostly the feeding (fish) that has the cost’’ (Lasse, 21.40 - 22.02).

Aquaponics system is a living organism system consisted of both animals and plants. Taking that into consideration and the fact that the system will be placed in the public school and used by the children we tried to ask questions about any legal requirements and safety concerns and challenges that may have to be handled to make the system safe for the children. Our respondent did think that there would be many of formal regulation on doing this in the school, but however he mentioned potential risks related to personal hygiene:

“Doing it right you should consider the pathogen content of what you are working with. If you want to have let’s say… produce something that could be used in the canteen or for the kids to eat. The pathogens will be introduced by the warm blooded animals and that’s the humans’’ (Lasse, 26.21 -28.06).

Then there are no pathogenic problems in the aquaponics cycle itself if the system is design well. Fish which are cold blooded do not carry pathogens. The bacteria in the system are also harmless to humans. The challenge would be to control the children in the classroom and avoid cross-contamination by putting e.g. contaminated fingers into the water or on the plants etc., and this can be helped by using gloves or having some hygienic routine when using the system. If the design parameters of an efficient aquaponics system is made well without any anaerobic zones building up putrid water, then the major concern is cross-contamination of pathogens from the users of the system. Additionally, because aquaponics is a system of growing plants and fish in a watery environment with a help of electrical supply, special care should be taken on any electrical connection and power supply:

"The electronic installation should be thought out good so that you won't have any contact or instability with water and electricity'' (Lasse, 28.56).

Having aquaponics system in a classroom demands monitoring and maintenance. Some of the challenges would be the amount of the task involved in the running of the system, who and when in the school should take care of it. In Lasses opinion it could be a potential problem or a concern with the system and the maintenance to keep it alive. It is mostly because there are living animals like fish and for some it may be stressful to see or have dying animals around:

"It is a concern with the vacations. Summer vacations that is three months or so and that is a consideration. Like are you taking out the fish for the summer? or is the janitor feeding the fish? or how is this working out?'' (Lasse, 30.14).

One of the challenges during school summer break would be decision of maintaining the system during the break or closing it down. It would be difficult for example to first shut up the system down for the summer period and start it all over again in September month when the children are coming back to school after the holiday break. It would be challenging to stabilize the system again, once the fish is taken out of the system:

“You would need to revitalize the microbial community by adding some ammonia to the system and see that you have the different bacterial groups occurring and then re-entering the fish, re-entering the plants’’ (Lasse, 32.49 -33.26).

In general terms, water quality and fish feed is another area with potential challenges that need to be taken care of (Yildiz et al., 2017). According to Lasse the chlorine levels in the tap water is not a concern in Denmark. The major problem with the tap water could be to keep the right pH levels, which allow fish and bacteria to grow in ideal conditions:

“This area as an example is slightly above 8 and the ideal pH for the system is slightly acidic so slightly below 7, between 6.5 and 7.5 and this is for the plants, the fish don’t care much depending on the fish’’ (Lasse, 34.10 - 42.46).

Depending on the fish in the system some fish like for example carp can thrive in pH range between 6 to 9, so the water can be bit acidic to them. In situation where water needs to be added to the system because of natural evaporation and water uptake by the plants a fluctuation in the pH of the water system can be noticed. In such situation when the pH of the water increases some acids such as phosphoric or nitrogen acids could be added to the system which in turn lower the water pH to levels adequate for the fish and nitrifying bacteria to flourish, and this could also use as a supplement to the plants (Lasse, 35:18).

When finally asked about the most important, challenging key aspects to consider in situation when constructing own aquaponics system in the school Lasse thought that the aesthetics of the system is very important for the overall sustainability of the concept that will be developed by choosing aesthetically pleasing materials. It is also important for the designers of the system to thoroughly think about the purposes the systems may serve in the school:

“This depends on the utility but figuring out if this is more of an ornamental low maintenance system then it will probably serve as a probe for fewer classes. However, if going up so it actually has some weight of productivity then it can be more cross disciplinarian and larger part of educational material’’ (Lasse, 46.01 - 50.40).

Lasse touches upon educational materials for different subjects that should be prepared by the teachers in advance for the lessons. By having ready materials and exercises on the different curriculum aspects aquaponics would probably be more user friendly to the teacher:

"I think it is critical also for the sustainability of a concept for an aquaponics design educational system is that you have a teaching plan that goes along with it that meets the different curriculum aspect and shows how you can work with these'' (Lasse, 46.01 - 50.40).

Additionally, standardized system design would also improve functionality of it, because it will be more convenient to re-do the exercises several times ''It is easier to have good quality of the education, if you know all the parameters (aquaponics) throughout'' (Lasse, 50.40).

Since Lasse works as a technician on remote aquaponics farm installation and occasionally uses the place to gives lectures about aquaponics. Primary school children with the teachers from the local schools are invited to participate in the external lecturing. When asked about any challenges or disadvantages of having a school based system versus a "central system'' as those at Osramhuset on location he meant that the maintenance and the cost of the system is the major concern if supplying aquaponics to a school. It could also put a bit of stress on the teachers to have some living animals in the classroom to take care of. In situation where the teachers or school leaders decide on having aquaponics in a school he wouldn't suggest too small a budget designated on building the system. He would recommend to allocate fund between 800 Danish crowns for a very small system, to slightly larger but still more for an ornamental system between 1000 to 2000 Danish crowns. So the challenge for the school would be to allocate those funds (Lasse, 50.40 – 58.16).

7.1.2. Daily work-life at school and challenges associated with the aquaponics.

This subsection of theme ‘’challenges’’ presents views of people directly involved in the aquaponics project in the school. Jacob a Physic teacher, Elizabeth and Mette both Biology teachers at Blågård Primary School in Copenhagen are colleagues who together took on the challenge of having an aquaponics system in the school. They were all interviewed and shared they views and opinions about the system. Additionally, data gained from the interview with the school headmaster and aquaponics post-implementation data from an interview with the children who participated in the system setup are presented in the section below.

When asked about their opinion about aquaponics system in education its relevance and importance as a part of a teaching tool in the primary school Jacob touched upon how the existing curriculum is built on, underlying strong dependence on theoretical knowledge. One of the challenges in modifying the current curriculum could include introduction of more practical aspect in the teaching and hands on activities:

“Here in school we have mostly theory and the kids do not have chance to see that in practice’’ (Jacob, 00:22-01:22).

Mette added that the teachers tried to teach children theories related to agriculture and plants nutritional needs. She admitted that the children don’t know what agriculture is, and they don’t have sense of plant growing and what they need:

“It was very difficult for the students because it was too abstract. They would not understand it because they do don’t have... they cannot make pictures’’ (Mette, 04:06-05:17).

Nevertheless, it is important to teach “city’’ students agriculture aspect, which can be at the same time sometimes demanding for biology teachers ‘’because some of them (children) have never been to a forest or have never been to the countryside’’ (Mette, 14:44-15:08).

Following on that as a teacher in primary school Jacob expressed his opinion what in his view could be a challenge or constraint that could actually make the implementation of the aquaponic system in the school difficult:

"The only thing is maybe… it's not a restriction as such, but if you have 25 kids in the class they all have to be active, otherwise it's very difficult for them to stay in touch with the topic which is thought in the lesson'' (Jacob, 03:17-04:17).

What could be difficult in his opinion is the task of actively engaging all children in the classroom in different activities and having control over it. The other aspect which is challenging for the teacher and which lies in teacher individual competences is to make the teaching interesting enough for the children to stay focused and engaged. Else a biology teacher in that instance mentioned difficulties she could encounter in taking care of the system, especially feeding the fish during off school periods:

*"There could be problems in the summertime when the school is closed during vacations, that could be the problem. I think, probably you would have to clean the aquarium sometimes'' (...) "the problem could maybe be vacation and the fish feeding'' (*Else, 06:18 – 07:11; *11:50 – 12:10).*

Mette pointed out potential problems with system maintenance not only during summer holiday but also in every day. This could be due to lack of will, motivation or interest in taking care of the living organisms, but also because teachers may lack time for any additional tasks.

"Until recently everything in here was dead, and there are reasons why nobody would maintain things alive in here'' (Mette, 02:47-03:20).

The role of students is very important in taking care of the system. In some instances, students would like to impress one another by for example killing animals. The older students, teenagers "need to play "cool" and they don't care about anything'' (Mette 08:30-08:57). The teachers challenge here would be to transform negative attitudes of some students and make them care of the living organisms:

"Jacob has a lot of stories about how students used to kill if there were life animals; fishes or snakes. Students would kill them just for fun''...''The children would go and pick them and crush them and I think that will be a challenge to make sure the students won't break anything or destroy anything just for fun''(Mette, 02:47– 03:42; 07:45-08:14).

When deciding on having a living organism system in a classroom such as aquaponics it is important for the teachers to answer themselves relevant question of having the ability to maintain it and for what period of time. When confronted with the question of ability to run the aquaponic system in the school, and the potential plans of using it in the future projects Jacob's reply was hesitant:

"I am not totally sure, but it seems like the system is very simple, and why not to try it... the only thing it's maybe... if I understand the system enough… it is the fish… you need to have the fish every time. Plants would be ok and all the other things. I think I understand it. It is the fish… you can buy them, of course. Gold fish are really quite tough aren't they?" (Jacob, 05:42-06:54).

The teachers are knowledgeable people and in fact the system at first seems easy to understand. Nevertheless, the aquaponic system to operate correctly needs basic understanding of not only individual system components and its functions, but also the interdependent relation of the elements in a closed-circuit environment. The above response can also indicate that some of the teachers may not fully realize that living organisms need constant care and the system needs to be monitored on a daily basis, which is time demanding task. Else's response was more balanced, since she seemed to be aware of the potential difficulties she may encounter, especially at the start of the project:

"It looks easy out there, but probably we will have a lot of problems at the start to find out how to run it and what plants to grow and then…''(Else, 12:10 – 13:27).

When confronted with the question of what could be the biggest limitation Jacob mention the possibility of lacking the time, and at the same time admitted that:

"I don't know how much it takes to maintain and take care of the system'' (Jacob, 09:05-09:35).

Else agreed with Jacob's first statement that teachers are lacking time of extra activities and that ''sometimes they (teachers) might be pressed'' (Else, 08:00 – 08:18). She stressed the need for engaged teachers willing to commit the time to make the project successful. She also shared a fear of not knowing how the system will operate:

"I don't know how much time it takes to make the system work and to grow the plants and to take care of them…" (Else, 07: 11 – 07:51).

When confronted with a follow up question of time that is allocated to conduct the normal lessons would be sufficient to actually introduce deeper concept about sustainability and general environmental issues because aquaponics will be part of practical sessions Jacob in that instance said that it would not be a problem *(Jacob, 10:56-11:43).*

It is also important to know if such a project could evoke natural interest in children. When confronted with a question about opinion of how many students would be interested in aquaponics Else replied:

“Hmm… I don’t quite know the school, because I come from the school where there is lot of attention, also among students who are interested in biology, physics and geography. But I don't think students here have the same interest in the school… but I hope to wake them up’’ (Else, 13:35 - 14:23).

Beyond the teaching issues teachers would be probably dealing with actual food, and maybe there would be produce coming out of the system. When asked about any plan of how to utilize the potential products there was actually no plan of how to use it:

“No, actually not’’ (Jacob, 12:22-13:15).

Furthermore, for large quantities of produce, Else was in doubt if the school had enough space for such production: ‘’I do not know if we (school) have space to produce enough food...’’ (Else, 20:56 - 22:10).

Mette also touched upon the collective understanding of the system and need for support from the school leaders in taking an active role in the project to make is successful. She would wish to make the school leadership more engaged in the actual classroom activities:

“No one else is coming into this room; the administration has never been here. The headmaster is not coming here. No one is coming here’’ (Mette, 13:31-13:39).

When the headmaster was asked about relevance and importance of aquaponics as a part of the educational curriculum in the school she agreed about its importance in making a change in the society, but at the same time stated that any teaching about aquaponics would have to be compatible with the Danish educational curriculum (Pia, 05:28-06:48). When confronted with a question about constraints or any challenges for implementing that in the school she could not visualize that because of her insufficient knowledge about the system in itself:

"I don't know, I don't know anything about it (...) I don't really know; I don't really understand how it would work'' (Pia, 11:03-11:21; 12:10- 12:23).

At the same time, she stated that it would be challenging for the teachers to take on extra activities in already busy teaching plan:

"That would be difficult for the teacher then. Too much to do now, I mean!'' (Pia, 15:56- 16:21).

After the system was in operation in the school for a month, information gathered from the children that participated in the focus group interview indicated another challenge. In general, they felt that they did not take an active part in different tasks of system care and maintenance:

"We don't really feel that we are doing anything with this…'' (P1-P4, 11:05 – 11:40).

Children would feel more engaged in the operation of the aquaponics if the activities were allocated among them and more responsibility given to them instead of the teachers: "*Because the teachers feed the fish''(P1, 11:05 – 11:40).*

7.2. Opportunities.

Another theme that emerged during the process of data collection was on the various opportunities that aquaponics stands to offer, particularly to the intended primary users of the system that is the school pupils. This opportunities category was vividly expressed by all informants as will be presented in this section of the thesis and we best tried to present all possibilities and opportunities we were able to identify literary as stated for there did not appear to be special or hidden meanings other than those expressed in respective contexts.

Lasse spoke highly of aquaponics in terms of its physical applications towards teaching. He stated that, it offers features that would be interesting to the teachers and the pupils as well. According to him, the aquaponics design makes it possible to display action by gravity as the water from the grow bed drains into the sump tank. These in our view, would be interesting to physics classes for pupils to learn about the natural laws and water flow through the pipes; in his words:

"...the siphon bell introduces some things with gravity and so on" (Lasse, 02:40).

While describing some of the aquaponics systems which he would recommend for a school, Lasse also mentioned another system called the Deep Water Culture (DWC) system. These according to him would offer greater visual display on the possibility of avoiding the use of soil as growing media since the roots get suspended in a liquid nutrient medium circulating throughout from the fish tank:

"Here you will be able to see the roots shoot into the water which gives you a plant with nothing else but the root which is also good for the education part" (Lasse, 04:18).

Lasse through his previous expertise, reaffirmed the possibility of scaling to size and on the flexibility of setting up different systems that satisfy different goals as required. He talked of innovative ways by use of cheap materials such as Intermediate Bulk Container (IBC). Such an approach can offer an opportunity and some possibility of having a system large enough to produce food that can be consumed at the school canteen. A 1000 liters IBC tot can be cut up such that the top, third size portion of the tank is turned around to be used as a grow bed, while using the larger bottom part of the tank as the fish tank. Doing that will provide you with 1sqm of growing area. However, the water volume of the fish tank could supply you with 4sqm of growing area. So it can be scaled like that meaning, if you bought two tots and cut one of them as the fish tank and one bed, then cut the other one in two, then you can have 3sqm of growing area.

"So it can be quite flexible depending on the need…Well it depends on the engagements and the budget and physical boundaries of the place. It could be an outdoor system, ... It could be in a greenhouse, it could be in a window seal, it could be in a foyer somewhere" (Lasse, 21:12).

Lasse further expressed the opportunity for active engagements by users in the care and maintenance of the system. He talked of role playing among the students, while the teachers act as facilitators in the process. These would be on the tasks such as feeding of the fish, and with the availability of funds, the system would also be automated. His remarks on these were:

"It could be the biology teacher doing that, when she is in the classroom. It could also be, if you wanted it to be a productive system; it could be with a timed feeder, or it could also be a part of some routine in the class, but it really depends on the level of the class you can get. And also the placing of the system, if it is in the particular classroom…, then it would be on them." (Lasse, 30:14-).

While still on the subject of automation and system requirements, Lasse talked of the use of artificial lighting; these would offer a great opportunity for the pupils to learn on the spectral aspects of light during science lesson especially within physics and about the various energy needs of the system. He said:

"You can also for more of educational aspect use LED lights in blue and red spectra and this will show the students that these are some of the lights that you have from the sun that you don't really think about… It also looks very technically interesting at the same time" (Lasse, 18:41-).

For air circulation into the system, Lasse made it clear that you do not need a different pump. He said that it would make an interesting part for teaching, how the same pump can be utilized to serve both functions that is; circulating water that carries adequate air with it. This presents an opportunity to learn how to minimize costs while meeting the essential needs of the system in a smart and efficient way:

"You can use the circulation pump to draw in air and there are some different physical principles that can be applied to do this. It could also serve as a component to the physics classes" (Lasse, 36:55-).

The evidence of waste conversion to useful and edible produce is a great opportunity for pupils to learn. Lasse made it a point that, indeed they can understand better the nutrient and waste cycling to produce food with minimal need to add extra nutrients that may be deficient. The extra additions are done in order to maintain the health of the system but only when there are signs of deficiency. This also offers opportunity to learn how to visually detect such problems on the plants:

"It is also a great educational value that you can go and try and eat the fish poop through a plant and it could also be interesting to add … a supplement and see the difference in the growth of the plant as something that has educational value. And you will be able also to boost the plant production and productivity by adding some micronutrients depending on the situation" (Lasse, 42:58-).

On the location and positioning of the system; Lasse talked of the opportunity presented by aquaponics being based at school when viewed as a multi discipline tool with frequent exposure compared to a central place. He was categorical in stating that even though the pupils can make excursions with the class having some excitement and in the process relieve stress from the teacher, that approach would be limiting in terms of time and exposure for meaningful learning:

"The advantage to having a system in the school is that the class will be able to follow the system over longer durations. And work with a lot of different curriculum aspects in different classes or cross disciplinary with the system. It is also possible to advance from quite a basic level to a higher level year to year working with the system. It also eh... it keeps the thing fresh and your mind's eye, you will be able to see the system on a regular basis" (Lasse, 51:04-).

Mette, the Biology teacher also concurred with Lasse's views on having a school based system adding that it is a better way to teach than the use of text materials. She also said that it would offer ease of access and thereby eliminate the need to make trips to production sites:

“I think it is just better than using text books and it is easier because it is here at the school. We don’t have to take a trip outside” (Mette, 00:14-00:41).

When confronted with the question of whether having both aquaponics and gardens at a school would be in conflict with the interest of the parties involved. He saw an opportunity for the systems to complement each other, in that aquaponics would for instance provide planting material which would be extended to gardens outside. In his words:

“… I think it could work quite well and I think on an integrational level of having an outdoor garden and maybe a small green house then it could serve very well to have a sprouting station in a greenhouse or in the school somewhere, where you have some fish and you have the cycle to sprout the plants that you are planting out for the outdoor” (Lasse, 03:36-)

On the subject of material availability, Lasse talked of how easy it is, to access all that may be required to set up a simple aquaponics system. He said that one can buy them from local suppliers and therefore with resources being available in terms of cash and the building materials, it presents a great opportunity to implement unlike in a situation where supplies would be a limiting factor. Asked about material access, he said:

“Yea, it is easiest like if you want to go and shop it all at once, then you go to a commodity store such as SILVAN, and then go to an aquarium store where you can get the pump, and some food and also a couple of fish if you don’t have that already” (Lasse, 10:33-10:52).

The use of aquaponics can offer opportunities for learning even to the educators; when asked on how she would incorporate it into teaching lessons, Mette expressed how even herself as a teacher would learn more about aquaponics and use it to teach:

“I don’t know very much about it, but I would like to learn more and I would like to use it in my classes” (...) “am hoping that I will learn a lot from it as well. That’s my main reason to do this.’’ (Mette, 01:11-01:28; 05:30-05:49).

She went on to explain the opportunity aquaponics would offer to the pupils in learning in a different style, one that reaffirms what is taught in theory from the various science subjects covered in the curriculum. she said that:

“Some of the students are very interested in any science education. And especially because they can test what we are talking about and they can watch it and they can make their own evaluations” (Mette, 01:54-02:22).

Mette saw an opportunity of directly using aquaponics into the current curriculum as part of an exam for upper primary pupils. Mette talked of the 9th grade and the new exams requirements, that it would offer some practicable applications:

“… The government has decided on, there is a… we need to teach the children about the nitrogen cycle. It is very important…maybe they can use it for their exams” (Mette, 04:06-05:16).

This application of aquaponics to the curriculum exams was proposed by another biology teacher, Else who said:

“And now I put in my program later on… we supposed to do a lot of nitrogen in the 9th grade, because they have to go to the exam, and then we can put back the reference to the course I think ‘’Can you remember …the drawing and so on’’. So I hope that will help them a lot” (Else, 02:05 – 03:22).

The head teacher further reinforced the need for practical’s and the opportunity that aquaponics would offer and how it would fit or be spaced within the curriculum, she too expressed the view that pupils would learn much better with it and that it would not be a problem having it included:

“I think you have to make the practical, because a lot of pupils, they are learning much better than... Yeees I think there is space for it.” (Pia, 13: 39-14:00).

For an aquaponics system to be successfully implemented at school, it is important to ensure that there are sufficient resources such as the money that would be used in its care and maintenance. The availability of money can provide an opportunity for success especially on the time to time needs such as provision of fish feeds. When confronted with the question of resource availability, Mette had this to say:

"We get money and we get resources for each subject like physics, biology and geography. It is one group and we get money each year, and we decide ourselves how to spend it. And, Else is the chief of our group. And she, I am sure has put money aside for this project. Like instead of buying books, she will take out to get money for the fishes" (Mette, 12:49-13:23).

The money issue was further confirmed by the physics teacher who said:

"The money for the fish, we can make a priority and it would be ok. We can do that, actually it is not a problem" (Jacob, 11:43-12:20).

Besides, Jacob seemed to appreciate the multidisciplinary nature of aquaponics in relation to teaching various subjects and therefore saw it as a great opportunity to teaching a wide range of subjects listing two as an example:

"Depending on if you are teaching Biology or Physics. It would be good if you have Physics you could take the nitrogen cycle, and you could follow it in the system. If it is Biology, I mean… you can put it into Agriculture theme for example and presents the way of growing plants where you do not pollute the surroundings" (Jacob, 04:34-05:40).

On future prospects and expansion of aquaponics within the school setting, the physics teacher said that the fish can even be on the roof in a pond, and he saw it as being very interesting if they could have it on the roof somehow which would offer a great opportunity to utilize more of the spaces that appear underutilized in the school. Jacob also saw it as a great opportunity for the pupils to learn about the source of food, where and how it is produced:

"It would be very beneficial for the kids. They would be able to understand the system if they had grown e.g. mint themselves. Children would be able to understand where it came from if they did it on their own, because they would understand the system" (Jacob, 12:22-13:15).

In addition, Pia even though she stressed on her lack of knowledge of aquaponics; she expressed some level of confidence in the teachers responsible and that aquaponics seemed to be a simpler way to teach complex things, an opportunity to make understanding less abstract to the pupils. These was derived from her response:

"I think a lot of our pupils would be interested in the education because you show them a difficult thing in a simple way" (Pia, 11:03-11:21).

Lastly, aquaponics can be considered as a mini version of an ecosystem exposing young children at school to nature. The head teacher saw it an opportunity to bring nature closer to the children considering that they don't know much about it. In her words, she said:

"I know a lot about the children…They'll like it. The children here, they only see their flat, and the school and the street. They don't know about nature; they never go in the woods. I think it is very good for them. I would like to bring them out in the nature, In the woods and the forest" (Pia, 16:58- 17:22).

She also said that the parents would certainly endorsed the aquaponics which would be a great opportunity for support from families and society at large as shown by her statement:

"yea, I know and the parents would love it" (Pia, 17:25-17:32).

She further envisioned a situation where the children would take home some of the produce from the harvest to their families, which is a great opportunity to extend the good in aquaponics beyond the school environment:

"…and if they make a lot of tomato, they would bring some of them home" (Pia,18:13- 18:27).

7.3. Relevance and Importance.

In this section issues of relevance and importance of aquaponics system in the primary school will be presented and analyzed. Relevance in this instance is a concept trying to connect aquaponics with existing educational curriculum in the primary education. Our respondents presented their opinion about how, or if aquaponic system in the classroom was relevant, as well as relevance of aquaponics as an educational helping aid, to educate students to become more environmentally aware citizens. It may be of importance in the process of finding a solution to relevant environmental problems in the future.

7.3.1. What is of relevance in the aquaponics system design.

Lasse was asked about what type of aquaponics system would be the most appropriate in the school environment. In his opinion one of the simplest system would be a simple "flood and drain'' system:

> *"So, you have a fish tank of some sort and a bed with gravel, then you make an auto-siphon in the bed, that makes an ebb and flow in the gravel bed, so the water goes directly from the fish tank to the gravel bed'' (Lasse, 00:17).*

The flood and drain system have a gravel container for the plants in which plant roots are buried and naturally divided into different root zone and filtration units. In that case the gravel bed serves as a sedimentation unit as well. Additionally, the gravel container can have worms in it, whose role is to decompose any organic matter. The surface of the gravel works as the biological surface area for the nitrifying bacteria.

In his opinion, the most practical aquaponic system in the school environment would probably be quite a simple system that does not need much care. It should be a system in place that ensures that the fish are fed twice a week or more. Fish feeding could be done either automated or it could be part of the caretaker's routine (Lasse, 32.09). Maintaining the correct water temperature is important to keep living organisms healthy. If the water flow is maintained and the water temperature is kept in the right range, it can be assured that the system will be operational. Likewise, increasing the temperature of the water will automatically boost the life of the system and the productivity. It is advisable to choose fish that are native to Denmark, which can actually survive in low temperatures water. It is also possible to change the type of vegetable production in winter time to plants that can tolerate very low temperatures:

"We want to keep the water over 5 degrees Celsius and this is primarily to sustain the microbial community as they will become dormant at lower degrees'' (Lasse, 48.50 - 49.03).

Most of the aquaponics systems do not need extra nutrients in order to maintain the health of the system. However, it is an important educational component to look at. By the help of different measurements, it is possible to determine any nutrient deficiencies and establish if potential deficiencies relate for example: the inadequate pH of the water in the system, the flow of the system and the mineralization of the system:

"It depends a lot on your management on the sediments on the system, if you go and re-mineralize the sediments of the system, you will have a fuller nutritional spectrum for the plant'' (Lasse, 44.49 - 45.06).

7.3.2. Relevance and importance of aquaponics in the educational realm.

Else thinks that aquaponics is very relevant in the primary education. In collaboration with other teachers who were very interested in the new technology, she planned to have such a system in the school one day (Else, 00:44 - 01:04). When asked about the reasons for having the system and how she would use it in the biology lesson, she replied:

"Because its biology…this is the thing with the fish and the plants and there is lots of biology and then the nutrients…" (Else, 01:04 – 01:40).

She added that there is a formal requirement from the Danish ministry to teach primary school children concepts about biogeochemical cycles such as nitrogen, carbon and water cycles. Aquaponics could be a tangible living example of a closed ecosystem, with a series of repeatable changes coming back to a starting point:

"I would use it in the school, because students have to learn about the circle of things going around; the carbon, the water and the nitrogen''(...). Definitely you can connect it to the teaching goals in the school'' (Else, 05:40 – 06:05; 10:00 – 11:20).

In Mette's opinion, children need to learn from hand on activities and validate the theoretical knowledge gained during lectures in practical exercises:

"I think it is very relevant because it is very concrete for students" (Mette, 00:14-00:41).

In addition, Jacob confirmed that the children would finding aquaponics interesting and inspiring. He acknowledged aquaponics as a very relevant tool in the process of educating young generations. He referred to sustainable aspects of aquaponics as an environmentally friendly food production technology, which can contribute to lower emissions of harmful gases into atmosphere:

"The climate and all the gases that we are worried about, and that we are going to do something about it, like using windmills or other environment friendly technology. It's all kind of... what you say? ... of things you could do to solve the problems, to make the atmosphere better''(...)"but it's very important that they (pupils) know that it is a problem and we have to solve it in a lot of different kind of ways. This is an interesting way of breaking the puzzle also" (Jacob, 01:24-03:17).

In the response above, Jacob touched upon on some of the advantages that aquaponics has to offer. It is believed that aquaponics uses up to 90% less water than traditional agriculture. The closed-loop ecosystem is a sustainable and environmentally friendly technology. It does not require vast spaces of land to cultivate vegetables and the use of chemicals to sustain productivity. Therefore, the quality of produce obtained is well-matched with those of organic production.

The school headmaster shared Jacob's views on how the technology can contribute to solve some of the global problems of climate change and malnutrition. However, she underlined that every individual should be self-responsible for their actions. In her opinion, adults should not put the burden of climate change or any environmental problems on the shoulders of the young generation:

“If we put all the problems on their shoulders, they will be lower, lower, lower. We have to show them the light. That is our wish” (Pia, 8:30-8:48).

At the same time, she agreed that the STEM model of teaching is very beneficial (Pia, 14:41), but she was not sure if the curriculum in Denmark is structured in a way that is compatible with that STEM approach:

“I don’t really know but I think, I think, if it is a good idea then yes’’ (Pia, 14:48-14:52).

7.4. Expectations.

The main focus in this section is on interviewees expectations in relation to aquaponics. The word expectation has multifaceted meaning here, depending on the interviewee individual needs. For instance, the expectation of the technician expert towards the system from a practical point of view may differ from expectations of teachers and students. All involved in the project have some expectations towards the aquaponic system undertaking, and this expectation could facilitate the setup of achievable goals and motivate individual actions.

7.4.1. Expectations of the technician as an educator.

The technician expects basically, that the system will be well kept and be operational in the future. He hopes for aquaponics classes to be expanded among different grades, allowing a large number of children to participate in the teaching. The teaching he implicitly stated, he would like to take an active role as an aquaponic instructor:

“And It is possible to do an aquaponics system with one or more of these classes’’ (Lasse, 59.02).

He mentioned the financial aspect connected with the cost of lecturing and materials. He wished that the school could share some expenses, and if this is not possible he would like to help in finding sponsorship:

"We would need to look at if the school can invest something on their own or we can get small sponsorship'' (Lasse, 59:20).

7.4.2. School expectations towards the new educational tool.

When Jacob was asked about his expectation for the system, apart from the important global warming problems issues he mentioned earlier, he said that; he expects to implement aquaponics in his Physics lessons to meet the requirements of the teaching curriculum. He mentioned that one of evaluation procedures could include explanation of one of the natural cycles:

"They (students) could also make a small animation, where they explain every step around in the cycle and tell about it in practice in this system'' (Jacob, 07:35-09:05).

He underlined that a larger part of the school students have different national backgrounds. He expects to use aquaponics system to grow culturally accepted plants that the students are familiar with. This could help in the process of evoking students interest in the system:

"Some of them make their own mint tea, because some of the students come from Morocco. You drink lot of mint tea down there. And it is a good point that the plant should be something children like and can associate with like basil and mint'' (Jacob, 13:15-13:55).

Else added to Jacob's opinion that a "surprising'' element of growing vegetables and following the growing process from the beginning would make the students more interested in the new technology:

"I think the point is maybe the surprising part of the system if you can see plant coming out and the fact that you can grow your own vegetables and so on… trying to make little surprise and the world more interesting'' (Else, 04:05 – 04:40).

In the focus group interview, children timidly, but nevertheless confirmed their willingness to continue using aquaponics in the class:

"Hmmm… (nodding head), Yeah… I think so… (inaudible conversation) (pause)'' (P1-4, 07:17 – 07:33), ''If you treat it well'' (P4, 07:17 – 07:33).

Moreover, because children have not been actively involved in using aquaponics, they expected to take more active role in the system maintenance on the daily basis:

"Maybe we could come out with the task of feeding them… (fish)'' (P1, 11:05 – 11:40).

It takes some responsibilities to run the system and knowledge to have control over it. Else expects that some professional caretaker would be visiting the school to check up if the system runs properly, especially in the initial phase of the project. In time, more responsibilities in the system maintenance should be taken over by the teachers:

"Maybe it would be a good idea that professional would be coming sometimes. Not every time but sometimes to check if we are doing well… I think that some of the teachers should be responsible for the aquaponics system, but then maybe you also need a professional...'' (Else, 12:10 – 13:27).

She also exposed her professional wishes as a new teacher in that school. She expressed a need for making her teaching profession more meaningful. It may be because in the previous school her vision of teaching did not match reality of everyday work:

"In the old school it went down the hill, even though it supposed to go up… I needed to get out of the school… (incoherent speech) … It is little hard to have all your visions fulfilled (…)'' (Else, 17:22 - 18:50).

Among many other methods, aquaponic system and goals connected with it could give sense and purpose in everyday life work of a teacher, if engaged enough. Aquaponics provides opportunity to concentrate on what is important not only professionally but also personally. The new goals assigned, if in line with the personal values could motivate to achieve something that is more meaningful. This in turn could contribute to achieve better work satisfaction.Mette is very excited to see how the aquaponics set up in the classroom work out. She expects that the students would see it as a learning project and at the same time being interested in watching how it develops (Mette, 03:42). As a special education teacher, in her opinion it will be possible to evaluate children's knowledge by a test. There is a lot of tests she can think of to apply; however, she hopes not to use formal tests as a method of checking children's knowledge. She would rather have the system standing in the classroom, where the students could see it every day, and by observing it they would be able to follow its progress:

''I hope we will not need to evaluate by testing, but just it will be incorporated in everyday life'' (Mette, 06:30-07:19).

7.5. Senses.

7.5.1. Perception of senses in the process of experiential learning.

Adolescents use their senses to gather information about surrounding world. In the process of learning all students have their preferred individual learning style. It is important for the teacher to keep in mind the role of senses in the process of learning while preparing learning materials that should reach all students. This section includes interviewees opinion about the role of senses in the process of learning.

Seeing may be perceived as one of the most important sense in the process of learning, especially for more visual students. Our technician thinks that the visual aspects of the aquaponic system will make the teaching more attractive:

''System design will increase the enjoyment of the system …it just works better'' (Lasse, 46.18).

According to Jacob the senses appeal followed by practical engagements using hands can be offered unlike in theoretical class situations, from his wording;

"The most interesting thing for me is that the kids can see in practice ehhh… circulation system… ehhh ecological system in function…. here you can see it..." (Jacob, 00:22-01:22).

Else together with Jacob added; when children could see the system in real life, it would be easier for them to understand some aspects of teaching:

"Here, they can see the connection…. It is here, it is here, it is here and now it is here again (knocking on the table) that is the strong thing about it. The nitrogen cycle is normally very difficult for the pupils to understand, it really is'' (Jacob, 07:35-09:05).

"I think that nitrogen was much easier to understand with aquaponics and bacterial and…'' (Else, 05:40 – 06:05).

Mette added to the previous response on the value of practical elements of hand on activities and the sense of smell:

"They (children) can touch it, and smell it and watch it and follow the process'' (Mette, 00:49-00:54).

Here children could benefit if they can put hands on something physical and even build the aquaponics system themselves. Mette hopes that the technology can have a practical implementation in the teaching:

"I am hoping that 9th grade students will see what we were talking about in the fall and they can see it now'' (Mette, 05:30-05:49).

Practical education can be entertaining for the children, supporting the need for creativity. Lasse thinks that it would be nice to taste some of the aquaponic product. In that way children would get more familiar with the technology and what it has to offer:

"It is nice to be able to try and eat something from the system'' (Lasse, 09:45-10:03).

Tasting the food can be of educational value. Tasting or even making small dishes from a produce children have grown themselves can be an enjoyable activity that will be remembered. It could be anything from tasting the herbs that are familiar to the children national cuisine, to making small vegetarian dishes from almost anything that is grown in the system. Jacob also mentioned; if the children had a grow bed with lot of herbs, it could be used to make for example a mint-tea that the children could enjoy drinking:

"Some of them make their own mint tea, because some of the students come from Morocco. You drink lot of mint tea down there'' (Jacob, 13:15-13:55).

7.6. Sustainability and Food literacy.

The concepts of sustainability and food literacy continue to occupy key positions in matters relating to the future of food production. The three main areas we considered following our understanding of sustainability in this context included: the ecological, economic and social factors. In this section, we attempted to carry out ethical reflections so as to clarify and evaluate underlying views and concerns as expressed by our informants. We hope that in identifying this key theme, we facilitate transparent discussions of socio-economic and political strategies that can be applied to meet the challenges of sustainable food production and enhanced food literacy.

Starting with an economic standpoint, while relating to resource usage; Lasse talked of the need to conserve or use less energy. These he said would be made possible while designing the aquaponics system. For instance, by limiting the height through which water is to be pumped from the sump tank to the fish tank and taking advantage of the force of gravity to drain water into the plant grow bed and further down into the sump tank, less energy is required by the pump for the circulation. In referring to the pumping; a major driver of the energy costs, he said:

" Yeah, of course you have a pump still but you don't lift it much. You don't need much head for the pump" (Lasse, 03:08-03:17).

The subject of sustainability also encompasses animal welfare when dealing food production. This aspect touches on the ecological component of sustainability. In our analysis, we identified an issue with the fish stocking density and the subsequent fish to plant ratios and the amount of feed given for a healthy and thriving system. In referring to "Biomass equation", Lasse talked about the ratio of fish to water volume and area of plant production area to body weight of the fish:

"I will say that you can have maybe 20, 25 kilos of fish per cubic of water'' (Lasse,13:20).

"If you want to talk about the productivity and how to sustain the plant growth, then you need to consider the input ratio… the body weight of fish to standing plants material is 1:3" (Lasse, 12:32-13:50).

Another relevant technique to calculate the productivity of plants that ensures a sustainable aquaponics system, touches on the measure of the fish feed input. If the system has a good filtration, then it is achievable to have one square meter of growing area for leafy greens per 15 grams of feed per day (Lasse, 15:02).

In aquaponics system, things are gradually progressing and things are being taken out or added in. If a fish is taken out of the system, it is necessary to ensure either, that the remaining fish could eat the extra amount of feed or to add more body mass to the system in order to have an efficient production.

Lasse also touched on the social aspects, talking of children's activities in class with the produce from aquaponics:

"Let's say (...) you have an output that you can use even in the class so everybody goes and takes a bit of mint and throws it in the glass and have some boiling water over so everybody is engaged in the system and then you start to work with the water cycle and so on"(Lasse, 23:01-).

If the system is well designed, it should be environmentally sustainable and no extra nutrients will be needed to maintain the health of the system. It is nevertheless important to feed the fish adequately in order to avoid fish malnutrition and nutrient deficiencies in the growing plants:

"We need to feed the fish right because that's the most critical part you don't want malnutrition of the fish. If you want a very productive system then depending on the species that you are growing and the design of the system itself, it can work very well without it" (Lasse, 42.58).

On the fish types and feeds, Lasse talked of different trophic levels of fish species and that these determine the kind of feeds that are given. To get a sustainable feed source according to our interviewee, it would probably be best to have herbivorous fish and feed them with some full nutritional feed that doesn't contain fish meal or bone powder:

"That we have plant eaters, and then we have omnivores species and then we have carnivores. So depending on what you are having in the system, your input will change on that. In my experience spirulina's will work very well as food for the system because spirulina has all the fatty acids there is and so it serves well as both fish feed and also as fertilizer for plants" (Lasse, 41:15-42:06).

Interestingly, on the topic of fish feeds, when asked about alternative feed sources, Lasse made the point that meat based feeds for fish result in more nutrient deficiencies on the resultant plant produce:

"Yea we have used some more meat based feeds as well. And we can see that the nutrient deficiencies of the plants have been much higher when using this type of feed" (Lasse, 42:16-).

Lasse also talked of a long term consideration to integrate the aquaponics with existing larger projects such as the school garden, suggesting that perhaps even scaling it up to have more utilizable food produce besides being used as an educational tool would make economic sense. He also said, that it would relieve stress from single subject teachers that are responsible for the small system. We interpreted this therefore as making it socially meaningful and comfortable for the teachers to run considering their other pressures such as time. Lasse had this to say on these issue:

"Let's say that you combine this with a school garden, then it becomes a more integrated part of the whole school and reduce the stress from the biology teacher. But it would be nice which also

broadens the understanding of the system. It could also make it possible to do a larger system with this interesting to see that you actually have some production capacity with some fish and some plants" (Lasse, 54:55-55:10-40).

From the individual teachers' perspectives, we got mixed expressions in relation to the literacy levels of the pupils contextually. This was especially true with regard to healthy foods and their origins. For instance, when Mette was asked about the students' knowledge of where their food comes from, like the production parts, she replied:

"NO, no no no. they don't know. The students here are very much city students, that's why it is difficult to have biology, because some of them have never been to a forest or have never been to the countryside. They live in the city" (Mette, 14:44-15:08).

However, when earlier on asked if the pupils had basic knowledge of nutrition and healthy foods, she had answered that they did indeed know in her opinion but didn't really care about it:

"Healthy food they can buy, very cheap but most of them bring their own food and I think they all know what is healthy, but like they don't really they don't care. They can just go down to Aldi or Netto (referring to a supermarket) and buy packs of chips and crisps and soda, and that's what they prefer" (Mette, 14:07-14:38).

The point about healthy food being supplied at the school canteen was also confirmed by Jacob:

"I think that around 90% of the food is organic and the food containers are made of environment friendly easy degradable materials as well" (Jacob, 14:55-15:35).

Else also tackled the issue of food from the point of its origin and related health perspectives. When confronted with the question of whether aquaponics would spark an interest in the pupils in learning about sustainable food production, she said:

"Yes, I think so… and I also have to teach that they just don't go down to the supermarket and buy the food. It is coming (food) from somewhere. We just have an issue on the 9th grade - '' are your food local or global? where the food is coming from." (Else, 04:50 - 05:20).

On the students' knowledge about healthy foods, composition etc. Else talked of a lesson she had had with the pupils, implying that they had been taught about it:

"We just have had this issue not that far than two months ago to find out what's in the food and what it contains and what do we have to eat to be healthy and why are we eating different stuff around the world" (Else, 15:58 - 17:10).

Else's statements were confirmed by information obtained from the pupils that participated during a focus group interview. Their responses indicated some reasonable level of knowledge on the specific areas that were of interest to us. When asked whether they knew where their foods are produced, and if they had any knowledge of what healthy food meant, they responded thus:

"Hmmm… meat comes from animals (P2, P3, P4 giggles) … like cows, and the vegetables comes from the seeds fra landet (from the countryside). The milk and cheese also comes from the animals… yeah" (P1, 02:13 – 02:30).

In responding to what healthy food meant to them, here is what the pupils had to say:

"Vegetables, beans hmmm… food with a lot of proteins, food which is not processed, food with no added sugars and…" (P1, P2, P3 agree) (P4, 02:33 – 03:33).

Lastly, Pia-the head teacher expressed some understanding and concern with environmental issues by touching on food waste and her own way of taking responsibility or contributing to the bigger puzzle of a sustainable food future. However, at the same time, she was rather skeptical that the approach of teaching the children first at schools, while their own parents don't share the same views can be a recipe for conflict back at home. In her own words:

"Sometimes I just think that we learn the children something that their own parents can't. And then they come home, then they crash, because they don't know anything about it. But they will tell, this is best for the nature, so we must be very careful not to put all our grown up problems into the kids" (Pia, 06:46).

She however shared the same views as the other teachers that the children lacked exposure to nature and that she wished to do more to change that:

"I know a lot about the children…The children here, they only see their flat, and the school and the street. They don't know about nature; they never go in the woods…I would like to bring them out in the nature, in the woods and the forest" (Pia, 16:58- 17:22).

When Pia was asked to give her views on current food production methods, and if she was concerned in any way about the way food is being produced, she was quick to give personal approaches through her actions. From these, we got insight into her way of thinking around the subject of sustainability and her knowledge around the subject of food waste and reuse. Her response was:

"but I am only eating potatoes and cheese…I take care of all that, and I am that kind of person that I use less instead of a lot and then throw it out. I use, some after they have taken something out of the table they throw it out. I reuse it again the next day" (Pia,18:40-19:50).

7.7. Stakeholders roles and engagement.

The subject of effectively engaging stakeholders is of critical importance for a successful implementation of any project. It is necessary to develop trust, practice integrity, understand people's views, seek and develop commitment and most importantly understand how to convert the project vision into reality. For the aquaponics project at the school, it was important to us that we coordinate well the stakeholders' involvement in the process. We sought to have their tangibility and accountability through their participation. The theme touching on stakeholder's is important, considering that the project involved many individuals as already covered in the KT frame as shown by those included in the sampling section.

Pia- the head teacher, mentioned others actors in the decision making and collaboration of any projects she undertook at the school. Beginning with the level and mode of interaction, in referring to the importance of communication, self-clarification and understanding of other people's opinions, she said:

"I think that to be honest, and to compare with, when you are not agreeing with somebody that you dare to tell them on the spot and then take the discussion without being angry, learn to have a dialogue, that you mean that, I mean this, so that to dare tell why and accept what you mean. That's the way to live together" (Pia, 01: 16- 01:54).

Pia was very insistent that the pupils' parents be involved which brought a new dimension on how deep in scope the project would reasonably go. It was a learning experience for us too as researchers from that perspective. In her expression:

"We have to speak to the grown up and their behavior has to change. Number 1. It is not the kids who shall go home and learn the grown-ups or their parents" (Pia, 06:47).

Pia also talked of some underlying factors pointing to other actors like politicians that she thought were responsible for the somewhat slow or no change at all in certain areas in society. For instance, when she insisted that children should not be burdened with bringing about future change, and that the adults especially the parents should do more on their part; she was confronted with the challenge to describe how she best thought change in society can come about. To this she replied:

"I don't see it happening, it is not happening, no it is not happening. Because the economic is making, it is not the wish that steer us. But it is the economic and I think the politicians, their philosophy is not clear any more…I don't think that the children are going to clean for us" (Pia, 07:32- 08:15).

While exploring the same issue of other relevant actors for successful implementation of the project, she was further asked about the role that the school leadership itself would play as a representative of the administration. The expectations were to find out areas of actor support in the operations relating to having the aquaponics system in the school. Here again, as her main emphasis; she insisted on the involvement of the parents as indicated in the statements below:

"First is to show it to the parents. I don't do it without the parents… it is not the children to bear it. We can't do anything here without the parents understanding and moderation…Yes, together

with the parents, because they tell us, do this in school, do this, do this, yes but we have, the parents have to go together with us. It is very important. (Pia, 09:47- 10:00; 10:10- 10:22; 20:02-20:17).

Pia, in her continual reference to the parents' involvement indicated that, it is a way for them to learn too, and that not much would be accomplished without them being central to the implementation of such a project:

"But the parents also have to learn. Because they have to change something" (Pia, 10:35-10:55).

The acknowledgement of the other teaching staff members by Pia, as having the potential to run the project was expressed, even though Pia herself was not very knowledgeable on matters aquaponics. In responding to the challenges that might be expected of the system, her specific reference to the teachers involved further indicated that they will be expected as key stakeholders to be knowing all that may be necessary to mitigate those problems and teach accordingly.

"I don't know, I don't know anything about it, but maybe Jacob or Mette (referring to the two project responsible teachers) will do something…yea I understand it but…I don't do this without the teachers. Because, they know what the pupils need to learn. What they need, what they have to learn. (Pia, 11:03-11:21; 15:22-15:40).

In addressing the question of resource allocation to any school project, Pia was categorical that a leadership team was always involved in making decisions and that she alone would not go ahead and implement any project without consultations. This she expressed thus:

"but I don't decide anything on my own. I always do it together with my leadership team" (Pia, 12:45-12:48).

On the subject of product utilization as part of the school meals program, when asked if produce like fish, leafy greens or fruits like tomatoes can be used in the school canteen. Pia stated clearly that at the moment it is not acceptable because the community provides food for the kids but that there is a possibility to change that in future. This therefore brought to the forefront the role that the community can play in seeing through the success of such a project that involves the production of actual foods. This was her response:

"No, no, no, no, we are not allowed to it. They have the…, the community bring us food. So we, we can't allow it now, but maybe later" (Pia, 17:55-18:05).

Jacob also touched on the community's role in the provision of food to the school and how it touched on individual pupils and families' backgrounds:

"Here in the school you can order a meal if parents pay for it. For the pupils from the poorer family the society covers the expenses" (Jacob, 14:30).

The other teachers interviewed also touched on other actors of relevance to the project. In responding to how the aquaponics would be used in the curriculum; Mette made a mention of a Government requirement which she expressed as:

"The government has decided on, there is a… we need to teach the children about the nitrogen cycle. It is very important" (Mette, 04:06)

Mette- the biology teacher also talked of a form of collaboration with fellow staff members in areas where she felt she needed more knowledge in responding to questions on the general care and maintenance of the system and on whether she would recommend aquaponics to other users.

"I can talk to Jacob and Else, they know a lot" … "Else has recommended it very much, and Jacob is very excited about it. So, I guess if we can make it work, I will for sure recommend it. Maybe to younger classes" (Mette, 06:06; 09:51-10:10)

In addressing the question on resources and for the day to day needs and operations of the system, she further expressed her optimism on the team of three teachers that had agreed to take it up upon themselves to implement and use the aquaponics:

"We just decided the three of us; Jacob, Else and I, that this is something we want to do and we want to, between the three of us take care of it and maintain it and use it in our lessons" (Mette, 10:59-11:29)

On the subject of the primary users of the system- that is the pupils who are perceived as receiving stakeholders; the teachers talked of the expected beneficiaries in approximate numbers for the intended learning: Jacob stated that; at least more than half of the pupils would be able to use the aquaponics at the school (Jacob, 09:38). Mette also talked of having about 10 students in each of her classes, and that she expected about half from each class to be very excited about the project and the other half wouldn't (Mette, 09:13-09:38).

Else, talked of a time she tried to initiate contact with the aquaponics expert and in her response, we were able to identify the need for proper collaboration with the knowledgeable others in the areas of interest especially where external educational trips to the site of production are done. Here is what she tried to detail:

"but I haven't done it that well this time, because Lasse was… (inaudible) when I got the course. I wrote that I would like to go, but this was a long time ago and he answered straight saying: yes, you can come, and I had to send him some time and dates. But then he didn't answer for a month and then I phoned him. So… in fact I didn't know if I supposed to get the course or not two days before" (Else, 02:05-03:02)

From the onset, when we approached Else, to ask if would be possible to have small, compact aquaponics system in the school, her response pointed to the other stakeholder, first identifying the technical person- Lasse and a fellow teacher- Jacob with whom she was to consult before moving forward to taking in the project:

"Yes, maybe we will try with Lasse. It just an idea of maybe having one. I will have to talk to Jacob who said we had a lot of stuff, maybe we can have it running" (Else, 03:35 – 03:55).

Responding to a question on the care and maintenance of the system, Else talked of another stakeholder that was responsible for taking care of a rooftop garden at the school. She expressed some consideration following Jacob's suggestion that they would be incorporated, to take care of the aquaponics unit during long holidays such as the summer breaks. Referring to the garden, she said:

"(...) So, Jacob suggests that we could have a deal with them (Taghaver), because they are coming a lot in the summertime, so maybe they can maintain these gardens and take care of aquaponics too. We don't know yet, but… hmm…but I can phone them" (Else, 06:18 – 07:11; 08:18)

8. Discussion.

8.1. The strength of a qualitative studies.

8.1.1. Validity and reliability of qualitative methods.

The overall study about relevance and usefulness of aquaponics in the primary school was based on qualitative interview methods. Results of qualitative studies those based on interview research may raise questions with regards to its objectivity. Objectivity here can refer to a method of producing reliable knowledge, absent from biases that may distort results of a study. In practice bias can be present at any stage of the of the study research, from the initial phase of study design, through data collection, data analysis and interpretation. Objectivism of a qualitative studies outcome can be recognized by the concepts of reliability and validity.

The quality of a study is closely related to the concept of "trustworthiness'' of a study results. As Seale (1999), mentioned in this work "trustworthiness of a research report lies at the heart of issues conventionally discussed as validity and reliability" (Seale, 1999, p. 266). Basically, reliability tries to answer the question of study results reproducibility - if the same study conducted by other researchers at different time point would result in the same outcome? Lower reliability may occur in situation where interviewee contradict itself during an interview, or give dissimilar answers to different interviewers, in case where the interview guide questions are identical. Moreover, reliability issues concern the work of researcher's self in the process of transcription and during analysis of the interviews. It is not obvious that the same raw interview material would be transcribed and analyzed alike by different researchers (Kvale, 2007). There are some authors such as Stenbacka (2001), who argues that the concept of reliability is not appropriate in qualitative study, because it includes element of "measurement'' characteristic in quantitative studies (Stenbacka 2001, p. 552). We could agree with the statement to the point where "measurement'' and any form of putting a figure on the results is characteristic in quantitative studies. The concept of "measurement'' here does not refer to any attempt to quantifying the data as a method, but rather instead in the process of evaluating the quality of qualitative studies. Validity on the other hand relates to the appropriateness of the method chosen to investigate a particular phenomenon, which in turn define the strength of the study results. As Steinar Kvale (2007) defined in his book by asking the question: "Are you measuring what you think you are measuring?" (Kvale, 2007). During the actual study course, the dates for the interviews with the teachers from practical reasons could not be scheduled same day. Some of the interview dates were scheduled in busier school periods than the other, like for example busy exam period before Christmas. This could influence the aspect of reliability to the answers given by the teachers, due to additional stress connected with extra work overload and deadlines that needed to be reached by the teachers. Secondly, by having long time lasting contact with the teachers we were able to get to know their daily work life at the school. In some instances, we could notice that the teachers during the interview tend to overestimate their ability to allocate the extra time needed to take care of the system. Additionally, the interview was conducted in English, and even though our interviewees assured us about their comfort we could observe some tension. Conversation in mother tongue is always superior to foreign language, because it is more authentic, where larger vocabulary allows deeper and more nuanced expression of thought. The task of transcribing and analyzing the interview was divided between two researchers. As researchers we are aware if different parts of the interviews were transcribed and analyzed by one another the results of the study could be slightly different. Nevertheless, we used our best abilities and agreed upon method of transcription and principles of analysis.

8.1.2. Generalizing qualitative interviews.

When the study results of a qualitative interviews are valid and reliable there is a question of findings generalizability – Could the study results be applied to larger population? In most of the cases the most frequent objections to the findings general application is the low number of participants taking part in the study. From statistical point of view generalization is possible, even with the small number of participants, if the participants are selected randomly and the results are quantified (Kvale, 2007). It is not the case in this qualitative case study where the convenience sample was chosen. It is however possible to use “analytical generalization’’ which involves realistic judgement about to what extent the results can be applied as a guidance in other situations (Kvale, 2007). According to Polit and Beck (2010) the main purpose of the most qualitative studies is: “not to generalize but rather to provide a rich, contextualized understanding of some aspect of human experience through the intensive study of particular cases’’ (Polit & Beck, 2010). We could conclude that the situation in other primary school, especially in the specific area of Copenhagen would be similar. It may consider aspects of teacher’s general lack of time and pressure in connection to reaching exams deadline. Teacher attitude toward taking part in the aquaponics is very optimistic, but based on our observation we came to conclusion that some teachers could overestimate their individual abilities.

8.2. Assessment of David Kolb’s experiential learning theory model.

David Kolb’s experiential learning model mentioned in the Theoretical Framework section describes learning processes as being circular. This can be understood in a way where a person, e.g. a student can experience physical occurrence, reflect about the new experience, think about it and form new concepts from that experience, then put the thoughts into action which leads to a new experience. This theoretical model visualizes process of personal development achieved by preferred individual learning style and by allowing time to critically think and act upon the experience. It should be noted that the learning cycle model does not have to be necessary initiated from Concrete Experience (CE) stage, but it can be set off from any other stage e.g. Abstract Conceptualization (AC) and the following stages of the model according to Kolb should be followed in the circle (Kolb 1984). The learning cycle is not however a closed circuit but the knowledge building process is continuous, based upon new experiences where knowledge is built in sort of spiral fashion. The process of learning is a lifelong course of action and knowledge is built and expanded based upon previous experiences. The model also indicates that every individual have predisposition to lean towards two learning modes. It is Kolb's schematic simplifications of human natural learning tendencies, which is not a fixed characteristic, but it can be modified depending on the subject and situation. The author of the models argues that mastering all of the teaching modes, will yield best results in learning processes. The issue of the acquiring ability of the learning modes by students and inclusion of the learning modes in the preparation of the teaching materials by the teachers was mentioned in an article written by Clare Forrest:

"Learners will tend to do what is easiest for them, which is to use their own preferred learning style. Similarly, trainers may train in ways that reflect their own learning style and may assume that all their learners will prefer to learn that way. Both approaches lead to incomplete learning – the reason why training may not be applied in the workplace. The trick is to ensure that each element of a training 'lesson' encourages students – and trainers - to use all the stages of the learning cycle'' (Forrest 2005).

Another approach to the learning styles was performed by Coffield and colleagues (2004), who analyzed the popular and quite often recommended concept of "matching'' the learning styles of students to the teaching styles of the educators as giving best results in academic performance for the students. The available studies of the "matching'' phenomenon were unclear and sometimes contradictory and did not contribute with evidence that matching of the learning styles plays a significant role in improved academic performance of the students (Coffield, et.al, 2004).

One of the advantages of the ELT learning cycle model is its simplicity and easy to understand description. Nevertheless, this simplification of learning cycle and learning modes might seem to be to narrow. In real life situations some of the learning stages may occur simultaneously like observing and thinking processes taking place at the same time and some of the ELT model stages may not be applicable at all. Moreover, there are other ways of learning and accommodating knowledge than experiential such as e.g. reading, listening, searching internet sources or talking to peers etc., which does not necessarily have to apply to all stages of the model. The definition of "experiential'' is crucial to interpret, because if all human actions fall under the definition of “experience’’ or “experiential learning’’ than would be justifiable call all the actions as an experiential learning. Tennant (1997) in his book commented that the ELT model is not applicable in all knowledge acquiring processes, giving as an example process of “memorizing’’ of information. Even though the learning modes are bond logically together with the different dimensions as a theoretical whole, this doesn’t necessary make them valid in all situations in learning practices (Tennant, 1997). Many authors appreciate David Kolb contribution into experiential learning theory which shifts the focus of learning from lecturer to learner. Alan Rogers author of few positions thematically touching upon course of teaching did not completely agreed with Kolb’s theory model by saying that: “learning includes goals, purposes, intentions, choice and decision-making, and it is not at all clear where these elements fit into the learning cycle" (Rogers, 1996, p. 108). It is not quite understood what the author meant by “intentions”, but the remaining characteristics could be found, probably implicitly in the model. Goals, purposes and decision-making are not explicitly integral elements of the ELT learning cycle model at such, but merely elements of the teaching programme design entrusted in the competences of the course responsible.

Miettinen (2000) in his article mentioned concept of experience and its popularity among educational theorists, because of its “ideological’’ role: “faith in an individual’s innate capacity to grow and learn’’, but at the same time based on philosophical studies argues that the ELT model of getting new knowledge in experiential learning is inadequate. He devotes special attention to the concept of “experience’’ which according to Kolb’s theory should lead and give basis for “reflection’’. According to the author Kolb did not managed to present any concept which joined the consequent experiential learning phases and therefore it seems as the phases are not connected to each other, but standing alone as separate modes. There is a missing link in the theoretical model describing the interrelation between experiential and conceptual. The foundation of scientific knowledge in David Kolb definition of learning as “a process whereby knowledge is created through the transformation of Experience’’ (Kolb 1984) has been questioned in philosophy of science circles. In empiricist theory of science knowledge is built on experiential perception relying on human senses as e.g. observation, but it may be prone to bias and prejudice (Miettinen, 2000).

It would be worth and advisable to conduct further research about learning processes common in different cultures. As Anderson (1988) in his early work mentioned that it would be of significant importance to consider any potential differences in ways of communication, information transmission and cognitive processes which are shaped and determined by different cultures (Anderson, 1988). Culture is one of the characteristics which determines who we are, how we learn and perceive ourselves in the society. Teaching, or channels of sending information which may be well understood in western cultures does not have to be perceived on the same level by people from different cultural background. The cultural differences aspects are mentioned here because it seems like the Kolb’s ELT model is build based on the “western’’ assumptions of understanding ourselves in the society. It is important to keep this in mind in the context of general multicultural Western societies in Europe and ethnical diversity in Denmark and the Danish schools.

8.3. Discussion of the results.

From the technical point of view to make a full-operational model of aquaponic in the primary school environment, appropriate design and basic understanding of the system elements and its function is advised. The most appropriate aquaponic system set up in the school as recommended by our technician, would be an easy to maintain simple “flood and drain’’ system, called CHIFT PIST (constant height in fish tank, pump in sump tank). There are other system solutions available online (Aquaponicsalive, n.d.). Any aquaponic system may consist of different number of containers for the plants to grow. The number of containers and materials from which the containers are made of can add to the overall cost of the system. There are also some individual components such as water pump, bell siphon and aquarium for the fish and fish feed that can add to the overall cost of the whole system. The system does not necessary need to be expensive. The Girraween primary school mentioned in the introductory part in the paper is an excellent example of how to build inexpensive system by combining imagination and readily available materials like in this case using a bathtub as a grow bed. Nevertheless, it is advised to make the system more esthetic to make it more attractive for the users which in turn could guarantee succession of the project in a long run. The estimated cost of an upgraded system would be around 1000 to 2000 Danish crowns.

It is important for the system caretakers to understand how the system operates. For instance, in order to have well-nourished and healthy plants the plants roots should not be constantly immersed in the water and it is crucial to understand the function of a bell siphon. Building up any anaerobic zones that makes putrid water should also be avoided. It is also essential to keep the right Ph levels or the water, which allow fish and bacteria to grow in ideal conditions. In order to achieve high productive and sustainable system it is necessary to consider the input ratios. It is important to take into consideration the appropriate fish mass to water volume ratio, and area of plant production area to body weight of the fish. Additionally, it is vital to feed the fish adequately also in summer time periods, in order to avoid fish malnutrition and nutrient deficiencies in the growing plants. For beginners in aquaponics there is a number of available home pages or blogs with practical user friendly guidelines of how to maintain the system (stuppy, n.d.).

Aquaponics as a living organism system demands monitoring and maintenance in a classroom. It would be necessary prior to deciding of having one to consider what need to be monitored, who and when in the school should be assigned for the tasks during in and out school periods. If not any technician would be assigned to take care of it, it could be problematic, because teachers in general complained about lack of time for additional activities. Some individuals in contrary sounded unrealistic and exaggerated the time they have for extra activities. In the future, if the teachers are more acquainted with the system, they could try to actively engage children in the system care and maintenance. It is also demanding for the teachers to control a large number of children in a classroom. It could be challenging both to actively engage children in the aquaponics tasks and at the same time to avoid cross-contamination by respecting some hygienic routine when using the system. Moreover, educational materials for different subjects should be prepared by the teachers in advance for the lessons. Some of the teaching materials including whole aquaponic educational curriculum can be found on internet pages such as Nelson & Pade, Inc. home page. By having ready materials and exercises on the different curriculum aspects, aquaponics would probably be more user friendly to the teacher. Some of the teachers express the need to modify the existing curriculum to include more practical aspect of teaching with hands on activities, because children’s knowledge about nature and agriculture is insufficient. Teachers in general found aquaponics relevant as part of the teaching taking into consideration the practical application of the system in a classroom. Children have need to learn from hand on activities and validate the theoretical knowledge gained during lectures in practical exercises. They stressed that children's cognitive development is shaped by experiences, understood and better experienced when all senses are engaged in the learning processes. In the process of learning individuals have their preferred learning style as those mentioned in David Kolb descriptions of the nine learning styles. It is important for the teacher to recognize children's individual learning styles to better compose learning materials that reach all students.

Additionally, school leadership was supportive towards aquaponic project and saw some perspectives in the technology, but in leaderships opinion any teaching about the aquaponics would be meaningful only if parents take an active role in the process of teaching. Beyond the teaching issues teachers would be probably dealing with actual food that needs plan how to utilize the potential products. This indicates the need for planning in advance for not only how to build and maintain the system, but also how to utilize the potential harvested product. Closer cooperation between teachers, school leadership and parents is underlined as a condition for successful project implementation. Additionally, different stakeholders involved in the project may have different needs connected to aquaponics. It would be worth to keep in mind individual stakeholder needs to make them satisfied and engaged, and the whole project successful. It could be anything from providing financial support designated for taking care for the system, increased students engagement, to fulfillment of individual educational needs of the teachers.

Another aspect worth discussing is the use of harvested produce from the system. From one of the interviews conducted with the teachers we learnt (from Jacob) that there was no actual plan on how they intended to use the products on harvest. This indicates a need for planning in advance, not only on how to build and maintain the system, but also how to utilize potential harvested produce. This issue could be less relevant in situations of limited production of plants and fish as was in our project, however in scaled up cases with expected larger product yields, an action plan for utilization would be preferred to be in place from the onset of the project. For example, depending on the type produce and the quantities harvested, some salad mixes would be introduced to the school cafeteria during lunch meals. A great deal of lessons would be borrowed from the examples identified in our thesis from other systems around the world. As an addition to our recommendations, it would be helpful to consider another good example of a successful STEM system, that was set up at Davis Elementary school in Arizona USA. Cheryl Schrader-Gerken, a Librarian at the time was responsible for the system and she learned Aquaponics herself and afterwards she passionately taught it to her Davis Elementary students. One of the factors for their success was due to expert consultation and the active involvement of the students. Davis helped her students to bravely touch tilapia fingerlings as illustrated in figure 18. The students were also guided in doing water quality measurements among other activities. There are many other illustrations depicting student activities resulting in what they term as "a STEM Teacher's dream with a drastic contrast to regular classrooms with bored students sitting at desks day dreaming" (Aquaponics USA, 2016).

Figure 18 Cheryl Schrader-Gerken helping one of her students touch a tilapia fingerling at Davis Elementary, Arizona (source: Aquaponics USA, 2016)

Consulting widely with experts in the subject on how to run their STEM Food Growing System was in our opinion a key pillar for success. In their case, they had the services of a Consultant, Professor, Research Scientist, who was working as a worldwide reference in Integrated Sustainable, AquaBioPonics, AquafuelPonics Systems and Humanitarian programs. A similar consultative approach would be well adapted for the Danish schools, as there is no shortage of knowledgeable experts in the field of aquaponics. For instance, schools around Copenhagen would make use of Lasse Antoni Karlsen, who played an active role in the initial stages of the system setup in our project. As for the Davis school, it is encouraging to note their success as something to learn from; what started as a small project in the Library ended up in a School Garden with a new coordinator Ashley Edgette who in the year 201 6, was quoted to have said:

"It is such a joy to be learning with kids out in the garden and inside with food making, art, science projects and Aquaponics- every morning before school begins, we hold an aquaponics club where kids from kindergarten through fifth grade run our Aquaponics system. In Aquaponics Club, we

feed our talapia, test the pH, Nitrates, Nitrites, and Ammonia levels of our fish tank, trim and harvest the vegetables, create Aquaponics related art projects, clean the Aquaponics water delivery rings and fill up the fish tank. We also do a monthly food day where we fry fish from our Aquaponics tank, make green smoothies from Aquaponics greens, or make homemade fruit juice." (Aquaponics USA, 2016)

It is worth reflecting on the perceived success towards the vision of using such a practical approach to bring about change in society. From our findings, we noted that the pupils had some basic knowledge of nutrition and healthy foods, but from Mette's response, she had answered that they did indeed know in her opinion but they didn't really care about it:

"Healthy food they can buy, very cheap but most of them bring their own food and I think they all know what is healthy, but like they don't really they don't care. They can just go down to Aldi or Netto (referring to a supermarket) and buy packs of chips and crisps and soda, and that's what they prefer" (Mette, 14:07-14:38).

This point about healthy food being supplied at the school canteen was confirmed by Jacob, *"I think that around 90% of the food is organic and the food containers are made of environment friendly easy degradable materials as well" (Jacob, 14:55-15:35). These* leave us with some questions that would be worthy investigating such as: why would the pupils prefer other foods that are traditionally considered "unhealthy"? and weather really aquaponics would have any long term effect on their perceptions to food, health and the environment?

On the subject of hesitation to introduce the pupils to the active and frequent use of the system as we learnt from the focus group interview; it is important to note that a significant body of research on the barriers to using technology in the classroom do exist. Hew & Brush (2007) identified some of the many barriers as: resource limitations, teacher knowledge and skills, and teacher attitudes and beliefs. According to Hew & Brush (2007), teachers tend not to use technology if they become frustrated when it does not work properly or when there is a lack of technical support in their school. Teachers also report having limited time to review and learn about new technology tools that they can use in their teaching and this was collaborated from our teacher interviews. The teacher knowledge and skills are also important factors in the use of technology in the classroom. Hew & Brush (2007) also reported that lack of specific technological skills is a common reason teachers give for not using technology. A possible challenge we noted through our observations was, that perhaps some educators felt intimidated by the technology, the thought that due to the involving details of the system touching on many disciplines, care and maintenance, they somehow couldn't introduce comprehensive student involvement on the aquaponics unit from the beginning or it seemed to be in a way challenging for them at the beginning. We simply think that, it signaled some discomfort of taking it further, but that would be addressed once they are well acquainted with the system workings. Unlike the students, who in the learning of various aspects for the first time may expect that the teachers are knowledgeable in the subject matter, it is understandable that adequate and relevant knowledge is with the educators before dissemination. It is therefore necessary to create a supportive environment where they (educators) won't have to feel incompetent when inquiring technical details. We think that educators using aquaponics should have some form of direct access to technocrats or practitioners who somehow figure out the technical details and share. It is acknowledged that the teachers also learn and try new things. Aquaponics as a relatively new phenomenon is a subject to evolve over time with more discoveries and improvements to be made.

8.4. Aquaponics technology for deeper understanding.

Today's children are bombarded with a lot of information in and out of the school environment. There is therefore competition for storage of information at the memory centers of the brain. Having considered the practical advantages that comes with physical tools like aquaponics, it is interesting to reflect widely on how long-term effects can be brought about by looking at memory so that what is learnt is not lost and can be adapted for future retrieval and use. How we learn and remember can be viewed from an information processing perspective in which learning can be considered as a change in knowledge in our stored memory. Atkinson & Shiffrin (1969) in their overall conception of the memory system talk of the storage and retrieval of information to and from the hypothesized stores. They argue that when attention is paid to inputs into our sensory register, these inputs or information become part of our working (short-term) memory and if we want to retain this information, it needs to be encoded into our stored (long-term) memory. Then we need to be able to retrieve this information from the stored memory to use it later and the decisions concerning how to store information will affect performance: storage via visual images may be more effective than auditory storage (Atkinson & Shiffrin (1969) c.f. Schnorr & Atkinson, 1969). In this respect, this effectiveness would be enhanced by visual tools such as an aquaponics system that eliminates the abstract construction of images which we propose facilitates long term retention and remembrance and therefore an enhanced long term learning and understanding would be assured. The teachers can support students to process information by helping them organize new information, and help the students link it to their existing or previous theoretical knowledge. An aquaponics system setup mimicking a natural ecosystem can be used to facilitate such a process. An interaction with the system might involve learning activities with the aquaponics system itself and/or as part of a lesson plan executed by the teacher within the curriculum requirements. Since our mission was in part to bring about meaningful change is society by enabling the young children to be problem solvers of the future with regard to the food system, we would like to recommend teaching adjustments to be made based on the five main educational theories that we have presented in this thesis in conjunction with a cognitive load theory developed by John Sweller in 1988. He argued that, learning resources must be designed to reduce the load on working memory in order to be able to construct schema. Sweller (1988) defined a schema as: "a structure which allows problem solvers to recognize a problem state as belonging to a particular category of problem states that normally require particular moves". This means, in effect, that the problem solver knows that certain problem states can be grouped, at least in part, by their similarity and the similarity of the moves that can be made from those states. Aquaponics can be seen as a complex integrated system which besides having the possibility to be used for individual subjects, can be applied to systems thinking and understanding relationships between individual parts that make the whole. This consideration enabled us to make a design that we consider to be effective on the resources and their optimal usage by the users. To deal with the complexity of learning materials that can be associated with aquaponics, and enhance the experiences of learners, we recommend provision of adequate access to aquaponics information such as the book resource we gave to the school teacher responsible on aquaponics farming. There are plenty of online links for more applications that can be used as would be desired. These guides can help the teachers in evaluating and assessing how they can directly cover the topics they teach, how they can clearly convey the information and have an understanding of how directly working with aquaponics would support student learning.

Lastly in focusing on the school usage of the system, we hope that as the project life continues beyond our conclusion of this study; that the teachers will be able to use the system in many ways, including: Offering lessons or demonstrations focusing on the topics such as sustainable development, nutrient cycling and health food production among others or as they shall find fit. We hope that the educators will take the students' abilities, needs, wishes and experiences into consideration while leading them through. We hope that they will go deeper to introduce students to the topics relating to sustainable food production and offer stimulus for group or whole-class discussion. By engaging students in activities that are not normally possible in a classroom setting and by allowing the students to work at their own pace will be considered an ultimate success going forward.

9. Conclusion.

The main purpose of this study was to explore possibilities for implementation of a fully operational aquaponic system into Danish primary school as a novel food production tool for teaching, demonstration and promotion of food literacy among school children. Aspects of opportunities as well as potential challenges that need to be considered, together with participant's individual perception of the aquaponic concepts were investigated. It can be concluded, even though the technology is seemingly complicated, it could be possibly applied in the primary school settings. It is central for the initiative takers to understand complexities of the technology and objectively estimate the available resources in their disposal, ranging from human, social to financial resources to avoid system failure. It is important to remember that the study results are based on qualitative interview methods with a small number of participants, who were directly involved into the aquaponic project setup. As an outcome very affluent and descriptive information were gathered, but it is not conclusive to generalize these findings to all educational institutions. However, some patterns such as: inadequate commitment of the system users, poor communication among stakeholders, especially in seeking consultation from experts and inadequate engagement of the pupils by the teachers were identified. To fully conclude on the successful implementation of using aquaponics at schools, more research is needed especially on evaluating the efficacy of aquaponics on improving food literacy.

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11. Appendices.

Appendix 1. The semi-structured questions of the interview guides.

Teachers Interview guide.

1. Would you find aquaponics relevant and important as a part of teaching? Why?
2. Would you like to participate and incorporate aquaponic in the teaching?
3. Do you think children would find it interesting and inspiring? Why
4. Any time constraints as a challenge to implementing, maintaining and using aquaponics?
5. Can you tell me about your goals/expectations/hopes for the system?
6. Do you think that aquaponics can be integrated into teaching curriculum and be able to meet the requirements? why, why not?
7. Do you think that your goals for the system could be met? How/why?
    - How would you evaluate teaching progress?
8. What would be the biggest limitations/challenges you could came up against?
9. How many students at your school will be impacted by aquaponics?
10. Would you recommend aquaponics to another teacher? Why?
11.Which subject areas would you teach using aquaponics? (Nutrition, agriculture,mathematics,

home-economics) why do you think it is relevant?

12. Is the time allocated sufficient to develop sustainable food-related life skills and introduce broader concepts of food literacy such as environmental sustainability?

13.How are material and financial resources allocated and are they sufficient?

14.Is there a supportive school food environment including the school canteen?

Technician expert Interview guide.

1. What start up system would you recommend for schools (specifications)?
   - Power, pump, fish to plant ratio, size, cost, type of fish, light etc.
2. Where we can the materials to build it? (material suppliers, also steady fish food supply)
3. Any legal requirements? (system and safety)
   - How can we make it safe for the children?
4. What would be the most suitable location at school to place the system?
5. Can schools expand this system in the future? How flexible is the design?
6. How much trouble is it to maintain it and who should do it in your opinion?
7. Any potential problems with the water or air pumps?
8. Can children make their own fish food?
9. Do we need to add any nutrients in order to maintain the health of the system?
10. What are the most important aspects?
11. What are the advantages/disadvantages of having central (school) or remote (e.g. Osram) aquaponics system?
12. Which of the above mentioned would you recommend?

Head-teacher Interview guide.

1. What would you say about the school's vision and mission and objectives in relation to students learning how are they realized in the day to day activities?
2. What are the three most important goals in relation to the school's vision and mission you would want to reach in your school?
   - Why do you consider those goals important?

3. What are your views on the education system and the best way to educating students?
4. What are the schools key values in relation to diversity and nurturing personal growth for students?
5. In your opinion would you find aquaponics relevant and important as a part of educational curriculum in this school?

- Why, or Why not?

6. Would the school leadership support incorporating of aquaponics in the school?

- Why, Why not, How?

7. Do you see any constraints or challenge for implementing, maintaining and using aquaponics? (would be in terms of Time, money allocation, etc.)

8. How are materials and financial resources allocated for practical subjects?
9. Is there extra time in the existing curriculum (Biology/Physics) to introduce a new topic?
10. Are you aware of the STEM model of teaching?

- Is the current educational curriculum somehow compatible with STEM (Science, Technology, Engineering) teaching?

11. What would be the biggest limitations/challenges you could came up against in relation to having aquaponics set up in your school?

- How would you handle it?

12. What (evidence) Results would you expect to see from effective aquaponics teaching?
13. Do you think children would find aquaponics interesting and inspiring?

- Why, Why not?

14. How many students at your school, do you think will be impacted by aquaponics?
15. Is there a supportive school food environment including the school canteen?
16. Are you concerned about the way food is produced conventionally? do you think there are any problems and consequences: In relation to health, climate change etc?

- what in your opinion should be done? and do the schools have a role to play in solving the problems?

Focus group interview guide.

1. Can anyone tell us where the food you eat comes from and how it is produced?
2. What does healthy food mean to you?
   - Why is it important to know where the food you eat comes from?
3. Can anyone tell us briefly what you have learnt about aquaponics during the last lessons.
   - Can anyone tell us briefly how aquaponics works?
   - What are some of the living things found in aquaponics?
   - What do you think about aquaponics?
4. Would you like to have and use aquaponics in the class?
5. Which part or component of aquaponics do you find most interesting?
   - Why?
6. Can anyone tell us anything disappointing about aquaponics?
   - Why?
7. Who or what could influence you in taking any role in caring of the aquaponics system?
   - Has anyone of you carried out any tasks on the system? -Which role did you act on? -How was it?
8. How would you like to use the products that are harvested from aquaponics?
9. Of all the things we've talked about, what is most important to you?

Appendix 2. The transcribed and coded interviews.

Jacob's coded interview (I - interviewer, J - Jacob).

I: Thank you Jacob for your participation in the interview and allocating your time to do that. We have a few questions to ask and it will take around 20 minutes. Feel free to answer according to your best knowledge. Just to underline that it's not knowledge checking interview, but just your personal opinion about the subject.

I: In your opinion would you find aquaponics system, aquaponics education relevant and important part of a teaching tool in the primary school?

J: Sure…sure… The most interesting thing for me is that the kids can see in practice ehhh… circulation system… ehhh ecological system in function. Here in school we have mostly theory and the kids do not have chance to see that in practice, here you can see it, and that it is… and actually you can measure different parts of the system. I find it very interesting that the practical aspect of the system is very strong (00:22-01:22).

I: I think the second question is kind of not relevant, because you already participate in the aquaponics system project, but what about the children. Do you think that children would find it interesting and inspiring in some way?

J: Yes… especially if… they have some knowledge background, where they have been introduced to… what do you call it?... the climate and all the gases in the climate that we are worried about and that we are going to do something about it, like using windmills or other environment friendly technology. It's all kind… what you say?… of things you could do to solve the problems, to make the atmosphere better (01:24-02:35).

I: You have raised the global warming issues right before, but are the children concerned about the global warming problems?

J: Hmm… concerned? I mean.. I'm very afraid of making them too concerned about it, but it's very important that they know that it's a problem and we have to solve it in a lot of different kind of ways. This is an interesting way of breaking the puzzle also (02:37-03:17).

I: As a teacher in primary school can you think of any challenges or constraints or anything else that can actually prevent actual implementation or maintenance of the aquaponic system from time schedules to resources and alike?

J: Hmmm… No, no, no I cannot see… the only thing is maybe… it's not a restriction as such, but if you have 25 kids in the class they all have to be active, otherwise it's very difficult for them to stay in touch with the topic which is thought in the lesson (03:17-04:17):
I: Ok, so you have to be able to employ all these children in different activities?
J: Exactly, that would be then very difficult (04:17-04:27).

I: What are your goals and expectations for the system apart from what you have touched upon certainly the global problem issue. What are your goals for the system particularly here in the classroom?

J: Hmm… as I said there are special goals depending on if you are teaching Biology or Physics. It would be good if you have Physics you could take the nitrogen cycle, and you could follow it in the system. If it is Biology, I mean… you can put it into Agriculture theme for example and presents the way of growing plants where you do not pollute the surroundings (04:34-05:40).

copyJ: Hmm… as I said there are special goals depending on if you are teaching Biology or Physics. It would be good if you have Physics you could take the nitrogen cycle, and you could follow it in the system. If it is Biology, I mean… you can put it into Agriculture theme for example and presents the way of growing plants where you do not pollute the surroundings (04:34-05:40).
I: Do you think you would be able to run the aquaponic system in the school in the future, is it a long time or single use project?
J: No, no… I am not totally sure, but it seems like the system is very simple, and why not to try it... the only thing it's maybe.. if I understand the system enough… it is the fish… you need to have the fish every time. Plants would be ok and all the other things. I think I understand it. It is the fish… you can buy them, of course. Gold fish are really quite tough aren't they? They can even be on the roof in a pond, even covered with ice if it is not on the bottom, they can leave there. And I think it's very interesting if we could have it on the roof somehow. We will

discussed that.

I: I think that there is a possibility for that (05:42-06:54).

I: Do you think that the system could be integrated in your existing curriculum?

J: Sure, sure, no problem. Biology and Physics would be brilliant. It fits exactly with the goals. It would be fantastic if we could have that (06:57:07:29).

I: Would you be able to meet the requirements of the teaching curriculum and how would you evaluate the teaching. Have you thought about it in Physics?

J: Yeah… Hmmm… (silence) well I mean… the evaluation could include explanation of the cycle approach. They could also make a small animation, where they explain every step around in the cycle and tell about it in practice in this system. Otherwise, if they would have to talk about the nitrogen cycle, they don't understand it. It's too abstract for them. Here, they can see the connection…. It is here , it is here, it is here and now it is here again (knocking on the table) that is the strong thing about it. The nitrogen cycle is normally very difficult for the pupils to understand, it really is (07:35-09:05).

I: What would be the biggest limitations for you in the school?

J: Maybe it would be the time… I don't know how much it takes to maintain and take care of the system (09:05-09:35).

I: What do you think, how many students will be able to use the aquaponics in this school, how many will be affected by that system?

J: Hmmmm…errrr… at least more than half of the pupils. I mean it is really difficult subject (09:38-10:05).

I: Would you recommend this system to other teachers in another schools?

J: Sure, sure. I am sure that it would be really nice system. Especially when you can put it into perspective like those big systems in United States we talked about earlier. If they can see that (pupils) I mean… we have a school system that we can make really big… wow (10:06-10:42).

I: The time that that is allocated to do conduct the normal lessons, because aquaponics will be part of practical sessions. Do you think that this time will be sufficient to actually introduce deeper concept about sustainability and general environmental issues for example?

J: Yeah, yeah… no problem no problem.
I: ok (10:56-11:43).

I: Do you think that there are enough materials or other resources for example to feed the fish and for the system maintenance and supervision?

J: The money for the fish we can make a priority and it would be ok. We can do that, actually it is not a problem (11:43-12:20).

I: Just beyond the teaching issues, you are dealing with actual food, maybe you would have a produce coming out of this, maybe it is mint or something else . Do you have a plan of how to utilize it?

J: No, actually not. But the result could be mint or something else. It would be very beneficial for the kids. They would be able to understand the system if they had grown e.g. mint themselves. Children would be able to understand where it came from if they did it on their own, because they would understood the system (12:22-13:15).
I: If children have a grow bed with lot of herbs, it could be for example basil which could be used in food or mint which children could use to make mint-tea and enjoy their own produce.
J: Some of them make their own mint tea, because some of the students come from Morocco. You drink lot of mint tea down there. And it is a good point that the plant should be something children like and can associate with like basil and mint (13:15-13:55).

I: Normally as a teacher you probably have a chance to observe children's knowledge about health, how they eat, are they making their own food or is there canteen in the school that makes the food? How does it run here?

J: Here in the school you can order a meal if parents pay for it. For the pupils from the poorer family the society covers the expenses. Every day at the 11:15 they go to the canteen and can eat the very often healthy meal.

I: So, the food is delivered from outside? You don't have your own canteen?

J: No it's from outside (14:00-14:55).

I: That's nice. At least they get exposed to good and healthy food.

J: Yes, they do.

I: And the essence is also a part of learning way of knowing that you can grow and prepare a healthy meal providing fish and protein etc.

J: I think that around 90% of the food is organic and the food containers are made of environment friendly easy degradable materials as well (14:55-15:35).

I: That is everything. Thank you Jacob for taking part in our interview.

J: You are welcome.

Mette's coded interview (I - interviewer, M - Mette).

I: Alright, I will go straight to the first question. would you find aquaponics relevant as part of the teaching and if so, why? (00-00:13)

M: Yes, I think it is very relevant because it is very concrete for the students, they can see it and smell it and watch it and learn from it. I think it is just better than using text books and it is easier because it is here at the school. We don't have to take a trip outside or yea. (00:14-00:41)

copyM: Yes, I think it is very relevant because it is very concrete for the students, they can see it and smell it and watch it and learn from it. I think it is just better than using text books and it is easier because it is here at the school. We don't have to take a trip outside or yea. (00:14-00:41)

I: so having it local is important for you and the sense that they can actually use their senses to learn in that way is interesting? (00:42-00:49)

M: yea, they can touch it, and smell it and watch it and follow the process. Yea (00:49-00:54)

I: would you like to participate and incorporate it in the teaching yourself, everytime… making it an integral part, like a necessity in teaching your lessons? (00:56-01:10)

M: yes, but I am a very new teacher in this subject biology, so I don’t know very much about it but I would like to learn more and I would like to use it in my classes. (01:11-01:28)

I: ok, so it is just like to find relevance, where it can fit in the curriculum and then it will be ok hopefully? (01:29-01:34)

M: yea and when I have learnt some of it myself. (01:35-01:39)

I: yea of course it is important to have an understanding before you can just push it to the students, in case they ask something then you are in a position to answer? (01:40-01:48)

M: yea

I: Do you think the children will be interested? Or will they find it inspiring? (01:49-01:53)

M: ehh, some of them will. Some of the students are very interested in any science education. And especially because they can test what we are talking about and they can watch it and they can make their own evaluations, so, I forgot the question. (01:54-02:22)

M: ehh, some of them will. Some of the students are very interested in any science education. And especially because they can test what we are talking about and they can watch it and they can make their own evaluations, so, I forgot the question. (01:54-02:22)

I: No no no, its ok, you’ve just actually answered it, it was about if and why you think the kids will be interested in it and will it inspire them to learn more or actually do it in practice? (02:22-02:33)

M: yea, yea (02:36)

I: Another thing is about the challenges, because we are trying to get if you think there is a challenge in implementing it or maintaining it, will that be a challenge here? (02:37-02:46)

M: Eeehmmm aaaa phh. I hope not, it is very new for both Jacob and I to do a project together, Else and I are both new teachers here, and until recently everything in here was dead, and the reason why is nobody would maintain things alive in here. And Jacob has a lot of stories about how students used to kill if there were life animals; fishes or snakes;(02:47-03:20)

I: Oohhh!!.

M: students would kill them just for fun. Yea, and so I am very excited to see how this will work out. But I hope they will see it as a learning project and be interested in watching how it will develop. (--3:42)

I: yea, probably I don't know if I should say something. But maybe it depends on the nature of the kind of animals or whatever was being raised? (3:43-

M: MMyeaa.

I: because, actually this is more in relation to food. So it shows you like there is a connection between where your food is coming from for example. (--

M: Mmmhh.

I: so I don't know if it's just snakes, and things like… you know, I don't know…, but that's an interesting input, we would like to look into why? (--04:05)

M: and I know in the 9th grade with the new exams, the government has decided on, there is a… we need to teach the children about the nitrogen cycle. It is very important, and we…, this fall, we did a…ahh…, we try to teach them about agriculture, and the nutrition's in the ground that plants needed. And it was very difficult for the students because it was too abstract. They would not understand it because they do don't have... they cannot make pictures. They don't know what agriculture is, they don't have any sense of plants growing and what they need. So, I think this would be very nice. I am very excited about it and I think Jacob is as well, that is why he was talking a lot about 9th grade and maybe they can use it for their exams. Well, but younger students, maybe they will just enjoy watching the fish and the plants. (04:06-05:17)

I: are you having any specific expectations for the system? Any hopes that may be it will make things better? (05:18- 05:29)

M: I am hoping as I just said that 9th grade students will see what we were talking about in the fall and they can see it now. Then am hoping that I will learn a lot from it as well. That's my main reason to do this, that I need to learn about it as well. (05:30-05:49)

I: and it is also because, it is an alternative system, it is not the way things are done out there, like in the dirt, in the soil, so probably you would expect a few questions, but yea, like you say if you learn something, then you will be able to present it better then. (05:50- 06:06)

M: and I can talk to Jacob and Else, they know a lot. (06:06-06:09)

I: alright, let's assume it is put in the system, and you have a way to teach in the class and all that, do you think you have a way that you can evaluate, can you check the progress of the students that they have learnt something? Is there a way that you can measure that? (06:10-06:29)

M: MMmhhh…I think a lot of the measurement with the special education children I have I done by what they are asking, the questions and their interests, and then of course it will be possible to evaluate by a test, there is a lot of tests that I can go and take, but I am hoping it will be more…ehhyjjj… cos it is standing here in the room, they will see it every day, they will watch, they will follow it so I hope we will not need to evaluate by testing, but just it will be incorporated in everyday life. (06:30-07:19)

I: because you will be having living things here, you will expect that they need some maintenance and care, do you think there are challenges, or if there is any greatest challenge that you can foresee or that even currently you will come up against in maintaining the system? (07:20-07:44)

M: Yea, as I told earlier, you can see my plants, the children would go and pick them and crush them and I think that will be a challenge to make sure the students won't break anything or destroy anything just for fun. The students cannot come in here (referring to the lab area) without a teacher so I guess we just have to watch them and then maybe talk to them why they shouldn't. (07:45-08:14)

I: do you think this applies to age, or it doesn't matter, it's just about the curiosity of the children because sometimes, "you" tend to think kids who cannot coordinate well, why they are destroying things, maybe they are young or? Do you think there is an age factor to this? (08:15-08:29)

M: I actually think the younger students would be more eager to maintain and take care of it. In the older students, there is a lot of teenagers who need to play "cool" and they don't care about anything, and the younger students would be more responsible I think. But I am not sure, maybe the students will surprise me. (08:30-08:57)

I: and actually, that kind of leads to our second question on this same idea about student participation. How many kids in your estimate do you think will be impacted in your class by this system? (08:58-09:12)

M: I have 3 different classes, and I will try to talk about it and show in all three classes. But I expect that maybe, and there is only about 10 students in each class, so I expect about half from each class will be very excited about this and the other half wouldn't. (09:13-09:38)

I: that's a good conservative number at least and a bit realistic, yea.; I: would you recommend aquaponics to any teacher, maybe for example in the staff and why if you will do? (09:39-09:50)

M: I am not sure what aquaponics is to be honest, but I will learn it. Else has recommended it very much, and Jacob is very excited about it. So, I guess if we can make it work, I will for sure recommend it. Maybe to younger classes. (09:51-10:10)

I: I have one more thing to ask about, ehh the support from the school for example. Because sometimes caring for these needs some input, for example feed for the fish, they're going to be fed. And maybe sometimes, you might need extra attention, because maybe if there is something more technical and maybe with the pH and something is dying, you need consultancy, maybe to call Lasse, and these things call for money for example. Do you think there is enough material support in that way from the institution? And are they sufficient, whatever is allocated for these practical's. (10:11-10:58)

M: we don't get extra time or any support for this, but we do it because we want to do it. It is not like we talked to the headmaster about it. We just decided the three of us; Jacob, Else and I, that this is something we want to do and we want to, between the three of us take care of it and maintain it and use it in our lessons. (10:59-11:29)

I: do you think it will be interesting to incorporate the management, like the school, not really management but administration? That is, we are talking of the principle and deputy- do you have that system here? M: yea, I: and maybe then, you will have more support, like the school is supporting this like maybe if it has a rooftop garden or something, then it is more, yea it is a good initiative but you have more like collective support? (11:30-11:53)

M: yea, I think it used to be like that, but it isn't any priority anymore. And I am not sure, like we don't get extra time: Else will probably do it in her spare time, I think come by, because she wants to and Jacob as well, he is very responsible about animals. (11:54-12:25)

TI: I have a question regarding this money, that the school cannot provide money but those fish, I mean they need to be fed. And the feed for the fish has to be bought, what do you think in the long run, who will provide for example resources for that or even though it is not much? (12:26-12:48)

M: we get money and we get resources for each like physics, biology and geography. It is one group and we get money each year, and we decide ourselves how to spend it. And, Else is the chief of our group. And she, I am sure has put money aside for this project. Like instead of buying books, she will take out to get money for the fishes. (12:49-13:23)

I: I think it is good as long as you have a collective understanding for those in that group, then it should be ok. (13:24-13:30)

M: But it's like no one else is coming into this room, the administration has never been here. The headmaster is not coming here. No one is coming here, (13:31-13:39)

TI: the headmaster doesn't know what's going on in the class? (13:40-13:42)

M: NOoo no no no, they don't know anything, only the cleaning lady and the teachers that teach here. But we would invite them. (13:43-13:51)

I: The last thing we wanted to talk about is the children's nutrition and the way they feed in the school, like do you have a canteen? Some kids, do they bring their own food? Do they know what is health food or not? (13:52-14:06)

M: yea, we have a lunch thing, downstairs where they get food from outside. Health food they can buy, very cheap but most of them bring their own food and I think they all know what is healthy, but like they don't really they don't care. They can just go down to Aldi or Netto (referring to a supermarket) and buy packs of chips and crisps and soda, and that's what they prefer. (14:07-14:38)

I: in your own opinion, do you think they know where their food comes from, like the production part of it? Most of them like really…(14:39-14:43)

M: NO, no no no. they don't know. The students here are very much city students, that's why it is difficult to have biology because some of them have never been to a forest or have never been to the countryside. They live in the city. (14:44-15:08)

TI: what about this eeehh… rooftop gardening, you have up there? would you actually use it for some teaching purposes in practice? (15:09-15:21)

M: yea,

TI: but I know it is another outside company who runs this garden, but there is a possibility here. Have you considered that? (15:22-15:28)

M: yea, I know, I think they used to but then they outsourced it because no one was really taking care of it. But it is another group and there is a very lovely, and there is a lot of plants and the bees and everything and young students are taking care of it all the summer. But the teachers here are using it for a GREAT ROOM, that's where the teachers go to when they don't want to see and talk to the students. But it would be used sure. (15:29-15:57)

I & TI: alright, I guess that's it. Thanks for your time, I hope we going to manage (15:58-16:07)

M: Mmm…No problem. (16:08)

Else's coded interview (I - interviewer, E - Else).

<u>I: In your opinion do you think aquaponics system, aquaponics education could be relevant and important part of a teaching tool in the primary school?</u>

E: Hmm…. yeah I think so. Actually I talked to Lasse who would like to try it in one school, and other teacher Jacob and I were very interested. So, maybe we are going to try it in the school to have aquaponics system running (00:44 - 01:04).

I: What was the reason behind it… I know you are teaching different subject in biology for example how would you use that?

E: Ehh… because its biology…this is the thing with the fish and the plants and there is lots of biology and then the nutrients… (01:04 – 01:40).

I: So, you are definitely for participating and incorporation of aquaponics into teaching system and putting into existing school curriculum? Do you think there's a room for it, where you could implement it in your program?

E: Yes, but I haven't done it that well this time, because Lasse was… (inaudible) when I got the course. I wrote that I would like to go, but this was a long time ago and he answered straight saying: yes you can come, and I had to send him some time and dates. But then he didn't answer for a month and then I phoned him. So… in fact I didn't know if I supposed to get the course or not two days before… so… Otherwise, if I am going next time out to him I will put it my programe of course. And now I put in my program later on, or I can… we supposed to do a lot of nitrogen in the 9th grade, because they have to go to the exam, and then we can put back the reference to the course I think ''Can you remember (inaudible) the drawing and so on''. So I hope that will help them a lot. (02:05 – 03:22).

I: Do you think it would be possible to have small, compact aquaponics system in the school?

E: Yes, maybe we will try with Lasse. It just an idea of maybe having one. I will have to talk to Jacob who said we had a lot of stuff, maybe we can have it running (03:35 – 03:55).

Copy E: Yes, maybe we will try with Lasse. It just an idea of maybe having one. I will have to talk to Jacob who said we had a lot of stuff, maybe we can have it running (03:35 – 03:55).

I: Do you think your students will be interested in having such system in the school, what would be the perception of aquaponics?

E: I think… maybe if we have some plants to grow and then… I think the point is maybe the surprising part of the system if you can see plant coming out and the fact that you can grow your own vegetables and so on… trying to make little surprise and the world more interesting (04:05 – 04:40).

Copy E: E: I think… maybe if we have some plants to grow and then… I think the point is maybe the surprising part of the system if you can see plant coming out and the fact that you can grow your own vegetables and so on… trying to make little surprise and the world more interesting (04:05 – 04:40).
I: Do you think that following the plant growing could make children be more interested in the system?
E: Yes, I think so… and I also have to teach that they just don't go down to the supermarket and buy the food. It is coming (food) from somewhere. We just have an issue on the 9th grade - '' are you food local or global'' where the food is coming from (04:50 - 05:20).

I: If the aquaponics was an integrated part of your curriculum, do you think there could be any challenges connected to the implementation of aquaponics ?

E: The challenge? Yes I think so… I use it in the school because those who have to learn about the circle of things going around the carbon and the water and the nitrogen. I think that nitrogen was much easier to understand than aquaponics and bacterial and… (05:40 – 06:05). I: But… maybe if I can clarify on that point we meant if there are any difficulties, problems to be able to run the aquaponics in the school?
E: Oh… ok problems…There could be problems in the summertime when the school is closed during vacations, that could be the problem. I think, probably you would have to clean the aquarium sometimes. So… but the a good thing is that on the roof actually we have a garden but it's not run by the school but by (Taghaver)… So, Jacob suggests that we could have a deal with them, because they are coming a lot in the summertime, so maybe they can maintain these gardens and take care of aquaponics too. We don't know yet, but… hmm… (06:18 – 07:11).

I: We know that the primary schools generally in Denmark are not that resourceful and teachers are quite often pressed with the time. Do you think this could be an issue?
E: Hmm… well… this could be an issue of course, but (silence) I don't know. I don't know how much time it takes to make the system work and to grow the plants and to take care of them… (07: 11 – 07:51).
I: I think that one you need more technical details before you can (…)?
E: Yes (07:51 – 08:00).
I: You need some quite engaged teachers willing to commit the time, because I can imagine they

don’t have time for extra activities?

E: Yes, sometimes they might be pressed (08:00 – 08:18).

I: But just before we proceed, I am interested in the garden you mentioned. Is there any connection with the school, do the kids have access to the garden?

E: No, no, but I can phone them (Taghaver) and make an arrangement and take my children up there to see the roof garden (…) I don't know if we can go up there now (…) It is used by another voluntary company… (08:18 – 09:06).

I: There are some teaching goals that teachers have to fulfill. How do you see the connection between aquaponics and the already set curriculum and set goals you have to achieve?

E: One of the goals is the nitrogen circle going around, so that could be… hehe… and ecological system as well is one of the goals and to understand that. I think there are lot of goals in there (09:06 – 09:50).

I: So do you think that your teaching goals can be met by this system?

E: Yes, yes definitely (09:50 – 10:00).

I: Do have any ideas how would you evaluate the students progress in teaching?

E: I think the… lot of them really got interested in the system and were surprised and… I think when we were there for the second time he (Lasse) asked questions regarding previous teaching when we were there for the first time and some of them (students) remember a lot of stuff… so that's good. But the problem I think… it was very cold out there, so I was scared that only few people would come for the second time, but there were almost all of them… that is good. But definitely you can connect it to the teaching goals in the school (10:00 – 11:20).

I: What would be the most difficult factors for implementing aquaponics here in the school?

E: Well… Jacob and other teaches said it is not a problem and it could be an good idea. Well I don't know… and he said that he had a lot of stuff which we could use for it. But the problem could maybe be vacation and the fish feeding (11:50 – 12:10).

I: Just to add on to that maybe because it takes few responsibilities to run this system. Do you think the pupils can be engaged to actually play a role in taking care of the system, or maybe there is a need for someone as professional caretaker to help from outside?

E: Maybe it would be a good idea that professional would be coming sometimes. Not every time but sometimes to check if we are doing well, that could be a good idea if Lasse could come along sometimes… I think that some of the teachers should be responsible for the aquaponics system, but then maybe you also need a professional... It looks easy out there, but probably we will have a lot of problems at the start to find out how to run it and what plants to grow and then…(12:10 – 13:27).

I: If you had such a system of aquaponics in the school do you think you could reach or evoke interest in students. Do you think that majority of the students will be interested in that?

E: Hmm… I don't quite know the school, because I come from the school where there is lot of attention, also among students who are interested in biology, physics and geography. But I don't think students here have the same interest in the school… but I hope to wake them up (13:35 - 14:23).

I: It's a good observation, because probably that is a big factor to know who is interested in this or not and how much effort to put into it.

E: Yes (14:34).

I: You see some positives in aquaponics, but would you recommend this to another teacher saying that this is a great tool you could use in different aspects?

E: Yes, yes but we are only few biology teachers. I think I'm the (…) third… And I don't know… our school is divided in three sections, so we have this building have the upper grade, and over there 4,5,6 grade and then we have small kids over there, so we are divided… (14:50 - 15:48).

I: Do you teach Home-economics in the school (…)?

E: Yes, we do.

I: Is it within biology or another subject?

E: In sub… (…) in both… we have topics running in (…) physics, chemistry, biology and geography. We just have had this issue not that far that two months ago to find out what's in the food and what it contains and what do we have to eat to be healthy and why are we eating different stuff around the world (15:58 - 17:10).

I: Do you feel that the time that is allocated is sufficient for these other extended studies like outside the normal school programme?

E: I tried to get out outside the school, that's probably why I got a new job, because in the old school it went down the hill, even though it supposed to go up… I needed to get out of the school… (incoherent speech)… It is little hard to have all your visions fulfilled (…) and the Danish teachers are pressed with reaching the deadline… and I've just found out yesterday that this school have free card to the zoo, so I can take the children to the zoo for free (17: 22 - 18:50). I: It's because we wanted to know if you can get enough time if you want your students to learn more about food literacy ''where its coming from'' ''what it contains'' and whether it's being produced in a sustainable way, whether the resources that the school is providing in terms of material, cash and the time is sufficient?

E: Definitely we do not have enough time. I'm little bit shocked because I used to have… well it has changed in my old school as well (…) In geography they have in 7grade two lessons, in 8 and 9 grade they have one 45 min lesson in a week. And sometimes we have school holidays or they have something else... I'm supposed to have (inaudible…) hours for one year: 90 for Biology, and then 120 for Physic and Chemistry, so it is very short time. In Geography I can hardly show them a documentary movie… so I think the time is a problem (18:55 - 20:41).
I: Especially when you have to think about something like aquaponics. It is very practical you know… to be hands on probably it takes lot of time to do this. This could be a limitation?
E: Yes, yes that could be a limitation (20:41 - 20:57).

I: Is there a canteen in the school? Do you think if this idea is sold to the management and the stuff - for example if you produce your own vegetables, is there another supporting environment like the school canteen where this food can be prepared?

E: Don't know, because they have a canteen called ''Just Eat'', so they have a special system in Copenhagen schools, so I don't know if you can produce food in this canteen, because the food is not prepared here is just semi-prepared here. Otherwise, the preparation is going somewhere else and food is being delivered and warmed up here or whatever. But it would be nice if we this could be possible, but I do not know if we have space to produce enough food... (20:56 - 22:10).

Copy E: Don't know, because they have a canteen called ‘’Just Eat’’, so they have a special system in Copenhagen schools, so I don't know if you can produce food in this canteen, because the food is not prepared here is just semi-prepared here. Otherwise, the preparation is going somewhere else and food is being delivered and warmed up here or whatever. But it would be nice if we this could be possible, but I do not know if we have space to produce enough food... (20:56 - 22:10).

I: We are thinking more about some kind of supplementary thing: you still have your own supply but you could use your vegetables and stuff not on a daily basis not relying on these, but additionally maybe. It would be nice to use what you produce.

E: That would be very nice (22:10 - 22:28).

I: I think that's about it, Thank you very much for your time.

E: Thank you.

Pia’s coded interview (I - interviewer, P - Pia).

I: what would you say about the school’s vision, mission and objectives in relations to the students learning and how are they realized in the day to day activities? (00-00:24)

P: (00:35-01:00) That the children here grow up and can manage themselves, that they will find eeh… education, job, so that they can take care of themselves in the community and to be to others what they wish others are being to them.

I: (01:02- 01:15) those sound like goals at the same time, are those the most important goals to you as the leader of the school?

P: (01: 16- 01:54) I think that to be honest, and to compare with when you are not agreeing with somebody that you dare to tell them on the spot and then take the discussion without being angry, learn to have a dialogue, that you mean that, I mean this, so that to dare tell why and accept what you mean. That’s the way to live together.

I: (01:56- 02:01) Do you consider that to be important and why is it important?

P: (02:03- 03:20) we all wish to live in peace, but it is very necessary when you don't agree with anyone. Then say it, instead of wish it. Say to that people you don't agree with so that you can, you all know where you are. I think it will be much easier. Also we have a lot of people, a lot of children which they have a very good home, then we have other children, they are in a family- where their social life- someone has either only the mother or the father and we have to meet with the kids the way they are, because they have to be much stronger, than a child from a family where they have sisters, brother, parents and the uncles.

I: (03:22-03:29) what are the key values in relation to diversity in the school and in what way do you nurture personal growth for the students?

P: (03:30-04:16) we meet the child where it is, but still you have to…eeehh the bar, *(am not speaking English so often, sharp laughter…I was living in Nigeria when I was a kid so …but it is, well I am not speaking so well.).* Children we meet, they have to learn, and learn and learn. You are here, but you have to go here, *(visually showing levels up with hands)*; all people have to have a progress.

I: (04:17- 04:22) so in relation to the school education system as it is now, do you think it is the best way to educate the students here?

P: (04. 23-04:59) the way we do now?

I: yea;

P: Yea, I think it is a good way but we have to weather the whole time, every day is a new day, we look at this day, how to manage this day, maybe we can use something we use tomorrow, a lot of things we have to find new ways., that's you have to when you are a school teacher, to be open. What do you need today what…individuals also? *(Too noisy to hear anything here)*

I: (05:15- 05:20) in your opinion would you find aquaponics relevant and important as a part of the educational curriculum in the school?

P: (05:28-06:48) Yea, but it has to, you have to be true to the (Dansk- pensum/- the children have to learn. Because I think we shall take care of childhood. I want the children to be in their childhood. Some of our grown up people's problems, we don't. we can't allow it to put it into the children. Because if you are not living good as a grown up, then you can't afford it from the children. Sometimes I just think that we learn the children something that their own parents can't. And then they come home, then they crash because, they don't know anything about it. But they will tell, this is best for the nature, so we must be very careful not to put all our grown up problems into the kids. We have to speak to the grown up and their behavior has to change. Number 1. It is not the kids who shall go home and learn the grown-ups or their parents, do you understand?

(I: mmhhh…, very interesting view!)

P: (06:50- 07:28) yes of course I know, and also a lot of teacher here, we learn children a lot of brrrrrr!!, yea, but their parents don't do it. A lot of children wish their parents don't smoke, but the parents smoke. Poor children, we have to say you have a childhood. From you are 0-16 yrs. And we shall not put all our problems into the kids. They can't, we have to go show them the way but we choose our own way.

I: (07:29- 07:31) How do you see change happening in societies then? Because normally…

P (07:32- 08:15) I don't see it happening, it is not happening, no it is not happening. Because the economic is making, it is not the wish that steer us. But it is the economic and I think the politicians, their philosophy is not clear any more. It is brrrr rrr rrrrhuuu rhuuu. I don't think that the children are going to clean for us.

copyP (07:32- 08:15) I don't see it happening, it is not happening, no it is not happening. Because the economic is making, it is not the wish that steer us. But it is the economic and I think the politicians, their philosophy is not clear any more. It is brrrr rrr rrrrhuuu rhuuu. I don't think that the children are going to clean for us.

TI: (08:16- Tomasz comment.) Depending on the way you are looking at it, some problems are put on the shoulders of the children, do you think that maybe it is another way not to make the children solve the problem but just to make them aware?

P: (8:30-8:48) yea yea, of course. Also give them some way to come out of it. Because if we put all the problems on their shoulders, they will be lower, lower, lower. We have to show them the light. That is our wish.

I: (08:49- but they won't remain children forever, when they grow up... So, when will they ever learn if they never learnt from the parents? and …. (Ps answer interrupted from beginning of question same time)

P: (08:50- 09:26) yea yea, I know, yea, yes. They have to put up a lot of learning in the kids. And when they are going to their education, then they can work for the community also. But I think a lot of parents are like; aahh! that is ok, my kid is learning this and this; I don't want to.

(I: mmhhh! that can be a challenge for sure!)

P: we have to look at ourselves number 1.

copyP: we have to look at ourselves number 1.

I: (09:33- 09:46) would the school leadership support the operation/or having of aquaponics in the school?

P: (09:47- 10:00) yes but I think the first is to show it to the parents. Don't do it without the parents.

P: (09:47- 10:00) yes but I think the first is to show it to the parents. Don't do it without the parents.

I: (10:01-10:09) If I hear you correctly; It is acceptable but at least all stakeholders need to be involved right?.

P: (10:10- 10:22) it is not the children to bear it. I think it is everyone. And the grown-ups are requested to do the vigorous. We can't do anything here without the parents understanding and moderation.

I: (10:32- what then, supposing the parents say, it is ok, this is a good tool, the students can use to learn about food?

P: (10:35-10:55) (interrupting question again.) But the parents also have to learn. Because they have to change something.

copy1P: (10:35-10:55) (interrupting question again.) But the parents also have to learn. Because they have to change something.

copy2P: (10:35-10:55) (interrupting question again.) But the parents also have to learn. Because they have to change something.

I: (10:44-) but then that will be very complicated, I don't know!!, that means they need another training or something?

P: (10:45-: it is very complicated. Yes, yes, yea.

I: (10:56- 11:02) do you see any constraints or any challenges for implementing that, it needs some care?

P: (11:03-11:21) *I don't know, I don't know anything about it*, but maybe Jacob or Mette will do something, but I think a lot of our pupils would be interested in the education because you show them a difficult thing in a simple way.

I: (11:37-11:41) on the practical issues, how in your opinion are materials or financial resources allocated for those practical subjects?

P: (11:45-12:05) Not really but we have some resources for books and computers and other things so it is, you have to choose what you want to buy, what you want to make.

I: (12:06-12:09) in your opinion do you think they are sufficient the way they are allocated?

P: (12:10- 12:23) I don't really know; I don't really understand how it would work.

P: (12:45-12:48) but I don't decide anything on my own. I always do it together with my leadership team.

copyP: (12:45-12:48) but I don't decide anything on my own. I always do it together with my leadership team.

TI: (12:49- 12:54) Ok, but as you said, there is some money allocated for the books and computers, so maybe some of the parts would be allocated to that piece of aquaponics?

P: (12:55- 13:02) Yea, yes, it would be, if the teachers around those subjects come and say we want this then there is no problem.

I: (13:26- 13:38) is there extra time in the existing curriculum, maybe in biology or physics to introduce a new topic for learning?

P: (13: 39-14:00). I don't know. (I: clarifying practical needs) I think you have to make the practical, because a lot of pupils, they are learning much better than... Yeees I think there is space for it.

I: (14:02-14:08) The STEM, model, have you heard of it?

P: 14:09- STEM, No.

P: 14:41- I think that is very good.

I: (14:41- 14:47) But the way the curriculum is arranged here in Denmark, do you think it is compatible with that STEM, approach?

P: (14:48-14:52) I don't really know but I think, I think, if it is a good idea then yes.

I: (14:54- 15:05) what do you think would be the biggest limitation, that you would come up against?

P: (15:06- 15:10) I can't, I can't really imagine.

TI: (15:11-15:22) you mentioned earlier the parents right, that the parents should be involved in the process?

P: (15:23-15:40) I don't really know what you are talking… asking me about! yea I understand it but…I don't do this without the teachers. Because, they know what the pupils need to learn. What they need, what they have to learn.

I: (15:55-15:50) what would be the administrative response for instance in a situation where a teacher spends more time on the project than allocated?

P: (15:56- 16:21) that would be difficult for the teacher then. Too much to do now, I mean! but then you can involve the pupils. They would take some of the responsibilities, maybe.

I: (16:31- 16:40) are there any expectations you can have from such a system; is there a way you would see or evaluate results if it is effective?

P: (16:41- 16:50) I don't know, I haven't thought about it, I don't know. I can't give you an honest answer to that question.

I: (16:58- 17:01) back on the children, do you think they can find it interesting?

P: (16:58- 17:22) I know a lot about the children, yes, yes of course. They like it. The children here, they only see their flat, and the school and the street. They don't know about nature; they never go in the woods. I think it is very good for them. I would like to bring them out in the nature. In the woods and the forest.

(I: (16:23- 17:27) but this brings nature here, because it is a small ecosystem. Which would be really)… (interrupted answer)

P: (17:25-17:32) yea, I know and the parents would love it.

I: (17:33- 17:37) do you have a rough estimate of students you think would be?… (interrupted answer)

P: (17:37- 17:40) I don't know, I can't (respondent laughter)

I: (17:50- for the produce e.g. Fish, leafy greens or fruit like tomatoes, is there a supportive environment in the school like a canteen where they can make use of the produce?

P: (17:55-18:05) No, no, no, no, we are not allowed to it. They have the, the community bring us food. So we, we can't allow it now. But maybe later.

TI: (18:06-18:12) so would it be possible if you have some produce, do you think it would be allowed to consume it, if for example you have tomato?

P: (18:13- 18:27) Yes, yes but then it would be around a class only. And not the whole school. Yea, the class yes, and if they make a lot of tomato, they would bring some of them home, yes. It is also alright of course.

I: (18:32-18:39) now on your general thoughts on food production. Are you concerned about the way food is produced, currently conventionally?

P: (18:40- but I am only eating potatoes and cheese.

(I: (18: 51) Laughter;) I: do you think there is a problem?

P: (18:52-19:01) it is a very, very big question, I can't just, eeeh, I wish….

(I: (19:02- 19:07) you don't have to discuss it exhaustively but just a brief on whether you think there is some problems, and yea... in relation to health, maybe or the climate- pollution)

P: (19:07-19:50) Yes of course, yes of course, I take care of all that and I am that kind of person that I use less instead of a lot and then throw it out. I use, some after they have taken something out of the table they throw it out. I reuse it again the next day.

I: (19:52- 19:58) in your opinion then, what do you think should be done? In the same way that you think that there is a problem, for example, do schools have any role to play in that?

P: (20:02-20:17) Yes, together with the parents, because they tell us, do this in school, do this, do this, yes but we have, the parents have to go together with us. It is very important.

TI: (20:18- 20:22) do the parents wish, to do this themselves?

P: 20:22- Maybe, maybe some of them.

TI: (20:28-20:31) so who is actually pushing you to cooperate with community like, teacher with parents, who is?

P: (20:33- 21:04) Nobody but that is…if you have to change anything. We have peace now, we can do anything with people, with children, but I think it is very important, it is our children, it is the parents' children, and we can't do everything, fix the children, sounds; tr tr tr no. the parents have to go together with us and make it up.

I: (21:12-12:50) On implementation to involve the parents, and conflict and priority with other administration agendas; if approached by a teacher, will you take the initiative to involve the parents?

P: (21:51- 22:26) No, no, because we have a lot of other projects now. And I have to focus on that. I have taught myself to say, only a few focus and then do it very good. And I will not take

this into my school now. No. Because, we haven't discussed it, we have a lot of other things that we have to implement. But maybe it would be in a year or two. But not in just…
Later on yes, it would be, because we want to use this park more, for exercising, so it would be, yes ok, ok.
I: Ok, thank you I guess that is all about it. I thank you very much for your time.
P: 22:50. Ok.

Lasse's coded interview (I - interviewer, L - Lasse).

I: what type of system do you think you recommend to schools for setting up an aquaponics system from your experience of the different types?

L: 00:17 Well I think. One of the simplest systems there is, is a simple flood and drain system. So you have a fish tank of some sort and a bed with gravel, then you make an auto-siphon in the bed, that makes an ebb and flow in the gravel bed, so the water goes directly from the fish tank to the gravel bed. The gravel bed serves as a sedimentation and has worms in it, it also the surface of the gravel works as the biological surface area for the nitrifying bacteria and it is also the container for the plants, so you have the root zone and the different filtration units in one.

01:22 Which also makes it a bit hard to distinguish but it's very simple. so Eeeeh... You can make this in two ways. There is a Concept called a constant height one pump system, that's a CHOP as an abbreviation.
And then there is a CHOP2 system. And in this systems you have a level of the water from the fish overflowing to the Plants. Another type of even more simple system is that, you just have the fish tank and the gravel bed on top. However, with the system with a small volume you will have differentiating water levels in the water tank which is not very good for the fish. So I would recommend to have constant height - the CHOP system.

02:40 It also implies some physical features that are interesting to the teachers and it employs the ballooning principle?? and a siphon bell and it also introduces some things with gravity and so on. (00:17-02:40)

I: OK. So it is just like to conserve or use less energy? to do all the pumping so that, kind of water flows by gravity down to the fish tank?

L: Yeah, of course you have a pump still but you don't lift it much. You don't need much head for the pump. (03:08-03:17)

I: Ok, yes, actually on the same question we would like to do more of follow up, or general detail overview questions. Because now you already know that this flood and drain system is probably the best suited for schools, but then it has On specific Setup requirements like power, requirements of the pump, the fish and plant ratios which would be used here. Can you talk about that, briefly some of the specifics. Like, what would be do able? to have these systems, and can they be worked out? like to have the right ratio of plants to fish and even cost estimates to do a setup?

L: 03:58 Yes; I will just jump back to previous question, eehh because you could do and turn it as an extension to the gravel bed and make a DWC which is Deep water culture.

04:18

That is a bed with only water in at a constant height with an air pump in and here you will be able to see the roots shoot into the water which gives you a plant with nothing else but the root which is also good for the education part.

04:36

On the costs and the setup, if we need the two containers, at least two maybe three or four for the fish tank and the beds and it is nice to have it transparent so that you can see it, just looking at the side of the system however it can create some difficulties with algae bloom. You need to place the system right; you don't want the aquarium exposed to sunlight.

And you can do this in many scales and we made one before, with the cost of a bit less than two hundred kroner, which we made out of 2 IKEA boxes, transparent boxes, and you can go and find this on our page. We made a separate page for the families' workshop that were here and build it, called Min VinduesFarm. Where we had a high transparent box and a shallower one that fitted perfectly on top of the other. We had the fish on the bottom one, a Small gravel bed, a pump that moved up the water and siphon in it and the two most expensive things was the pump. It costed 80 kr. i think, and the siphon bell; it consists of four-five different components. We try to reduce the costs of the components by not having a bulkhead fitting in the connection for the drain in the grow bed but it is quite expensive, it costs around 80-100kr. For a small one like that. So instead we made a bit more innovative solution which kind of worked and served at the same time.

07:12 You can also scale it up a bit. Doing it a bit more aesthetically pleasing using a real aquarium and finding some nice container for your water bed. The cheapest way is to get this from one used somewhere but it's a bit hard to plan it out. Usually, the schools also have aquariums, but you really want to go for something that has a standardized design.

07:52 For non-transparent containers, we have also been working with the masonry plastic tops. Black tops which are nice because you can get one that is round which performs well for an example of an aquaculture tank. Where you can make a flow at a tangent spring and water having a hole in the middle to suck up the water and creating a nice circular flow to get all the sediments and stuff out at once. And you can get another masonry top, at this ……... that serves good as both a gravel bed container or a deep water culture container. (03:58-08:49)

I: Ok, so if I can follow up on that. It sounds like these materials are actually available, easily available within Denmark if you want to set up the system?

08:58 L: mhmmhh..

I: 09:00 Are there like any specific concerns, like you have to use food grade kind of plastic for the fish and things like that?

L: that is a consideration primarily concerns to... if you want to eat the product that comes out, so you would like something that is food grade for this purpose. It is possible to get similar containers that are made for containing food. (09:12-09:35)

I: So it basically depends on what your project is for? I mean it would be just for beauty, ornamental or just to learn the kids or if it is for commercial production then these requirements come in?

L: Yea, but also if you want to make something standardized for the school classes and you want it to be a cross-disciplinary experience, then it is nice to be able to try and eat something from the system and then that will be a consideration. (09:45-10:03)

copyL: Yea, but also if you want to make something standardized for the school classes and you want it to be a cross-disciplinary experience, then it is nice to be able to try and eat something from the system and then that will be a consideration. (09:45-10:03)

TI: But also you mention you can get some of the equipment in stores such as IKEA right?

L: yea, IKEA or SILVAN or any type of commodities store.
I: 10:13 actually that answers our second question because we wanted to know where we can source those materials to build up, the suppliers and things like that)
I: Something that you maybe have not addressed has got to do with the fish food. Is it also easy to access this from the suppliers, can you buy it or can't you…?

L: Yea, it is easiest like if you want to go and shop it all at once, then you go to a commodity store such as SILVAN, and then go to an aquarium store where you can get the pump, and some food and also a couple of fish if you don't have that already. (10:33-10:52)

I: OK perfect, and once you talk about the whole system, am going back again into question one because actually if we address this one, most these questions will be covered. You already now know that you can set up a small system with this pump which is quite cheap probably. You know the power that it can supply. Can you now work out the details of how many fish can I keep in this system? how many plants just to get started? because sometimes it can be confusing if you are setting up a whole system and the circulation is not meeting all the demands!

L: Mhhh, So design and budget wise?

I: Yes.

L: you need a pump that can move the water at least one and have to two times of the fish tank volume per hour.

I: Ok.

L: So say we have 100litres of water container then you need a pump that can pump between hundred and fifty to 200 litres per hour. And it is important in the design consideration to see the height of the lift that the pump needs to take because pumps has a head (11.26-12:14).

I: 12:15 I guess that is quite understandable. So, but again if you talk about maybe working out from the pump. Then you know the volume that you can work with, and this volume, can you use it to determine then how many fish you get to start with?

L: 12:32 yes that was the other question, so the biomass equation?

I: Yes.

L: In common terms you usually talk about, or layman terms you talk about the ratio of fish to water volume. And area of plant production area to body weight of the fish, however, if you want to talk about the productivity and how to sustain the plant growth, then you need to consider the input ratio.

Copy L: In common terms you usually talk about, or layman terms you talk about the ratio of fish to water volume. And area of plant production area to body weight of the fish, however, if you want to talk about the productivity and how to sustain the plant growth, then you need to consider the input ratio.

I: so, there are many other factors that come into play?

L: 13:20 with that being said, then it is with a simple system like a gravel bed system. I will say that you can have maybe 20, 25 kilos of fish per cubic?? of water. And if advancing and also having…, you can also go lower.

I: so it is scalable anyway depending on what you want to set up?

L: 13:50 Yeah, eeehh, you can go lower and the body weight of fish to standing plants material is 1:3.

I: Ok

L: But in reality you want to look at the input to the system and this can be a major flaw. So you should be probably not be looking at a very fine tuned system where you want a great out and input. But usually you would go and calculate the productivity of the plants on the input of the feed. And if having a good filtration system, where you mineralize all the stuff and re-mineralize the sediments which is a bit technical, then you will be able to have one square meter of growing area for leafy greens per 15 grams of feed per day.

15:02

However, we are much lower in our ratios. But this is if you want to do it like efficient production and make maximum yield of your produce. But the fish can go for quite long without having much to eat, they need some for their metabolic processes but can go dormant for some time. So you can really go and scale it to the need of the place.

I: 15:34 is it possible to know the output by what you are feeding the fish?. Can you kind of tell, this is the yield of the poop or whatever that is and then kind of make an estimate of the nutrients?

L: 15:54 Yea, and if you know that you have fish enough to your plant bed area, and that you have plant enough and you have planted at the right time and you have a succession. Then it is very possible to go and say that you will be able to take this much out, depending on the plant of course.

I: 16:15 Another technical part on that is, if you have your own set up of fish here and you know they are growing, so obviously you are feeding more and they're growing they're producing more and the plants are kind of fixed there. Then there comes a time you probably have to harvest. If it is not constantly there, How do you maintain this system such that, you know if you are taking out these kind of old fish and then are you putting in new small fish? Or you need another tank to continue so that the plants are not running out of nutrient supply?

L: 16:50 Mmmhh, in this particular system, things are gradually progressing and things are being added on and we had this aquarium for a startup and we have fewer fish than the amount of feed that we would like to put into this square metres of plant area that we do have. And if we took fish out of the system we would either need to increase and ensure that the fish could eat the extra amount of feed or we would need to add more body mass to the system in order to have an efficient production. With that being said it can be quite flexible depending on the need. I have seen educational systems from the scale of half a meter to up to more standardized systems in the States where you get, I think it's 750 litre circular tank for the fish with a peacolumn??? on the side and then you have maybe 5-8 sq. metres of growing area. And this could prove as a small input to the daily meal of… or the canteen or something like that.

I: 18:25

IT: I do have one question regarding the thing you mentioned that the system, or the aquarium shouldn't stand in direct sunlight. But are there any other requirements in terms of lighting for the system or for the plants?

L: 18:41 Well the plants need light and that depends on the plant itself but the light will also determine the productivity and the filtration capacity of the root zone. So you can have it just in face of light if exposed anywhere. You can also supply with either supplemental light or pure artificial light, however it adds a lot of cost to the system and it also takes electricity. It also makes it more prone to errors because you would probably want to meet somewhere where you had some light but still keeping your cost down. So the best in the lighting situation would be to have supplemental light because then you know that you have some where all the spectrum for the plant needs. You can get something that is quite inexpensive by using this fluorescent lights called T5, T8 you can also use for aquariums. However, it proves best to the sprouting phase if applied. You can also for more of educational aspect use, and also electricity wise use LED lights in blue and red spectra and this will show the students that these are some of the lights that you have from the sun that you don't really think about however it creates quite unpleasant working environment. It also looks very technically interesting at the same time.

I: 20.45 That could take us to actually question four because when you talk about light and this is about where in a school situation could you place your system. So in this case you are considering maybe is it an open set up in a class, is it an open space area set up or under a greenhouse for example something like that. So in a school set up, what in your opinion would be ??

L: 21.12 Well it depends on the engagements and the budget and physical boundaries of the place. It could be an outdoor system it makes it a bit less controlled though. It could be in a greenhouse, it could be in a window seal, it could be in a foyer somewhere.

I: 21.40 Well, does it have any impact on resources? because we are thinking about sustainability in this sense. Like, if I put it in-house that is going to cost probably more like bringing in the artificial lighting and controlled systems much more than you can take advantage of the outside for example in terms of aeration, sunlight and things like that?

L: 22.02 Yeah but depends on how you make it if you can have the systems outside but you will have a lot of other interferences in the system. Which I think will also disturb the explanation value of the system

IT: 22.30 But in your opinion what will be the most cost effective system you are talking about setting such a system in a school and all the schools are running with the, always with financial difficulties. What will be your best option?

L: 22.46 It depends on what the ambition with the system is. If like you can scale it quite down and let's say you have..

IT: 22.57 This is for educational purposes?

L: 23.01 Yea but educational purposes can go on for any scale…, because it is also a great educational value that you can go and try and eat the fish poop through a plant. So what I just talked with these teachers about that is you can take something that takes low maintenance to grow and doesn't take that you go and replant all the time and such as mint let's say we have window seal like this, half a meter times 30 to 40 cm in depth. If you fill one up with mints or such you have low maintenance and you have an output that you can use even in the class so everybody goes and takes a bit of mint and throws it in the glass and have some boiling water over so everybody is engaged in the system and then you start to work with the water cycle and so on. You can also go up a bit also to sort of show some of the things that people do eat and buy from the shops and so on lettuces and things like this could also be something 1sq meter of production can give quite a lot. A very simple setup that you can do if you have 1sqm at the site. Is that you can have an IPC tot like this, that is cubic 1000litre tots that we have up there. You cut up the top third of the tank and turn that one around, use the large part of the tank as the fish tank and use the cut out piece as the growing area and that will provide you with 1sqm of growing area. However, the water volume of the tank could supply you with actually 4sqm of growing area. So you can scale it like that. if you bought two tots and cut one of them as the fish tank and one bed and then cut the other one in two then you have 3sqm and quite much water. That could be a system and if you want to move that much water it could cost around 400-500 kr per pump then the gravel also gets up to, so you will also need to use some kroners on that. The drain pipes and such cost almost the same no matter the bio-meter it is mostly the feeding that has the cost.

I: 26.21 Ok, so if we look at the system in terms of legal requirements is there, are there safety concerns, anything that is like... how can it be made safe for the kids?

L: 26.44 I don't think there would be much real regulation on doing this. However, doing it right you should consider the pathogen content of what you are working with if you want to have let's say cubic of water to produce maybe 5 or 6sqm so you actually produce something that could be used in the canteen or for the kids to eat. Then there are no pathogenic problems in the cycle itself. Fish are cold blooded and do not carry pathogens the bacteria also harness so the pathogens will be introduced by the warm blooded animals and that's the humans. So the way to prevent this is that you don't put your fingers into the thing and this can be helped by using gloves or having some hygienic routine when using the system.

I: 28.06 Yeah, so essentially there is an understanding about this how to make it safe for everybody, the kids and whoever who is running the system right?

L: 28.15 Yeah, and then of course you want to have the cycle running as it should. So the design parameters of making an efficient aquaponics system should be made so you don't have anaerobic zones building up and putrid water and yea and a healthy system that is designed right, then the only worry is pathogens from the users of the system. But that can be sustained on the cycle as well.

I: 28.47 Yea, Perfect thank you, we go to …

IT: 28.50 I was just thinking don't you have any bacteria or pathogens on the plants in itself?

L: 28.56 No, that need to be introduced. yea there is fungi and bacteria but they are not really harmful. It's just general hygienic routines when using it and then there is on the safety all in all on the electronic installation should be thought out good so that you won't have any contact or instability with water and electricity.

I: 29.31 Yea, because it might have this shock system and we are using power and stuff?

L: 29.35 Yeah, it is a concern and it should be in the manual on how to set it up.

I: 29.45 And then this is more general on the trouble of maintenance. If you are running the system now, how much trouble is it to maintain it? and in your opinion who should do it? If there is the technical issue is it, I mean, can the kids for example manage it? do you have to have a professional taking care of the system?

L: 30.14 It depends a lot on the design of it. And what could be a potential problem or a concern with the system and the maintenance is mostly that you are keeping animals and you are having fish. And it is stressful to have dying animals around. But it really depends on the design let's say you have a few goldfish and you can feed them a couple of time of the week. It could be the biology teacher doing that when she is in the classroom. It could also, if you wanted it to be a productive system it could be with a timed feeder, it has a bit of a cost, it could also be a part of some routine in the class but it really depends on the level of the class you can get. And also the placing of the system, if it is in the particular classroom…, then it would be on them. It if is in the biology room, then they are probably only there a couple of times of the week, however the teacher is coming by. It is a concern with the vacations. Summer vacations that is three months or so and that is a consideration. Like Are you taking out the fish for the summer? or is the janitor feeding the fish? or how is this working out?

IT: 31.56 What is your opinion about it? What would be the most practical way to do it if you have such a set of system set up in a school, what to do during the summer holiday?

L: 32.09 Probably having quite an extensive system that does not need much care and having some system in place that ensures that they are fed twice a week or a bit more depending on the system. it could be either automated or it could be just general routine for the caretakers of the place. You could also take the fish home to somebody, however, then the microbial community of the system will die out.

IT: 32.49 Would it be difficult for example to first shut up the system down, for the summer period and start it all over again from for example September month when the children are coming back to school after the end of August?

L: 33.01 Yes, but then you need to revitalize the microbial community by adding some ammonia to the system and see that you have the different bacterial groups occurring and then re-entering the fish, re-entering the plants.

I: 33.20 Is that also the thing with the cycling? that you have to do to ensure that the system is stabilizing before you start to do…?

L: 33.26 Yea, we need to do this over and over again if you are taking out the fish out the system.

I: 33.34 It is like you are starting over again?

L: 33.36 Yeah. You could make some nutrient dosing for when you are not there. However, if you put ready-made nutrients into the system then there is nothing for the microbes to feed on still. But It doesn't need to be a super big problem like we are on vacation here sometime, and they are fed a couple of days a week by somebody, we always make some arrangement and it is not that difficult.

I: 34.10 Yea, something also on the inputs, actually if you are considering like water are there any potential problems with the water that you use in the system? The quality of the water and even additions later on because it gets taken by the plant and all these fish … how do you go around that?

L: 34.30 So the tap water in Denmark, last time you asked me and you also meet this in most American literature that chlorine would be a concern, but it is not a lot in Denmark, so that is not a problem. Major problem with tap water is the PH, that this area as an example is slightly above 8 and the ideal PH for the system is slightly acidic so slightly below 7, between 6.5 and 7.5 and this is for the plants, the fish don't care much depending on the fish, let's take the carp; they can go almost up to 9 or down to 6.5 or 6. So it is a bit acidic to them. That also means that when you are adding up water to the system, you will see a fluctuation in the PH of the system. And so You might need to add an acid to the system. This could be phosphoric acid or a nitrogen acid and this could also use as a supplement to the plants. And on evaporation or the adding up to the system because you have evapotranspiration through the plants and you also have the uptake of water in through the plants and you have general evaporation through the surfaces. So you will need to add up water.

copyL: 34.30 So the tap water in Denmark, last time you asked me and you also meet this in most American literature that chlorine would be a concern, but it is not a lot in Denmark, so that is not a problem. Major problem with tap water is the PH, that this area as an example is slightly above 8 and the ideal PH for the system is slightly acidic so slightly below 7, between 6.5 and 7.5 and this is for the plants, the fish don't care much depending on the fish, let's take the carp; they can go almost up to 9 or down to 6.5 or 6. So it is a bit acidic to them. That also means that when you are adding up water to the system, you will see a fluctuation in the PH of the system. And so You might need to add an acid to the system. This could be phosphoric acid or a nitrogen acid and this could also use as a supplement to the plants. And on evaporation or the adding up to the system because you have evapotranspiration through the plants and you also have the uptake of water in through the plants and you have general evaporation through the surfaces. So you will need to add up water.

I: 36.36 Ok, but it is not so much of a difference actually.

L: No… not.

I: Ok. Eeh... What about the air circulation? I mean you need kind of, to make sure there is good supply of air to the fish and all that, then do you need a different pump or the water pump itself can be used?

L: 36.55 You can use the circulation pump to draw in air and there is some different physical principles that can be applied to do this. It could also serve as a component to the physics classes. One way is that with the siphon, we have used the Bernoulli's principle to make the siphon bell work as if breaking the surface of the water tank with the water spraying out on the top, the you will give some oxygen. You can also use the Venturi principle and using the direct pumping from the pumps, it pumps the water in, that increases the diameter of the tube or the piping when you have a small input for a narrow horse and then when the rare horse has an exit or entrance that is higher than the water level in the system and that is then, that when the water comes in it changes its speed and then it goes into a more narrow tube again and this will draw in air so you can create quite a lot of airborne that will hold all the oxygen that you will need from this. It takes some of the energy from the pump, but if you have a separate tank for the pump; a sump-tank, and the system is made so the pump moves water from that one to the fish tank then you can make the aeration doing that. However, an air pump is not very expensive and it takes quite low wattage but it is nice to keep it down to some simple components, even you could do the whole circulation with an air pump. Where you make an airlift but this is a bit more technical but you could do it. I have seen some plug and play aquaculture systems which is like a cubic in a circular tank and a biofilter just with bits and sediment filter on the side and then the whole circulation is run just with one big compressor that makes the water move.

I: 40.00 Ok. So down to more of the inputs again. Maybe, I remember last time we talked about the fish food. And to think of a sustainable way to do it instead of feeding against small fish from the seas and the cycle is actually in the end not very sustainable in this. Do you think that the children can learn how to make their own fish food supply?

L: 40.22 I think you could work with it as a part of their education but I don't think you should rely on it. To get a sustainable feed source it would probably be smart to have herbivorous fish and feed them with some full nutritional feed that doesn't contain fish meal or bone powder this could be spirulina that has all the nutrients and the amino acids.

I: 41.01 Oh so actually, I just learnt something, like you have different types of fish, there are some which are basically herbivores which can depend on plant nutrition and some really need to feed on other fish and other stuff?

L: 41.15 Yeah, so that is C. So the effluent of spirulina when the fish eats it has quite a full eehh…

Copy L: 41.15 Yeah, so that is different trophic levels that we are talking about that. We have plant eaters, and then we have omnivores species and then we have carnivores. So Depending on what you are having in the system, your input will change on that. In my experience spirulina's will work very well as food for the system because spirulina has all the fatty acids there is and so it serves well as both fish feed and also as fertilizer for plants. So the effluent of spirulina when the fish eats it has quite a full eehh…

I: 42.08 It's like a benefit, you know you don't have to filter this much kind of dumping it out, it can be used directly on the plants, right?

L.42.16 Yea we have used some more meat based feeds as well. And We can see that the nutrient deficiencies of the plants have been much higher when using this type of feed.

I: 42.32 Ok
IT: meat based you say, what type is it?

L: 42.36 Well most fish feed that you can get are based on fish oils and fish bone powders.

I: 42.46 And That actually brings us then to… say,do we need to add extra nutrients in order to maintain the health of the system?

L: 42.58 We don't need. we need to feed the fish right because that's the most critical part you don't want malnutrition of the fish. If you want a very productive system then depending on the species that you are growing and the design of the system itself, you could be needing additional nutrients but this is if you really want to have something very efficient going on it can work very well without it. However, it is good educational components to look at; do we have nutrient deficiencies? does this relate to the PH of the system to the flow of the system and to the mineralization of the system? Can that be improved? That is incremental maintenance? but if you experience that you are lacking something and that you work out these parameters and you are still lacking iron or magnesium or such. It could also be interesting to add it as a supplement and see the difference in the growth of the plant as something that has educational value. And you will be able also to boost the plant production and productivity by adding some micronutrients depending on the situation and the feed and how the system is going. But usually it would be iron, manganese, magnesium and such.

I: 44.49 And Probably the type of produce can actually determine! because I have learnt that if you are producing like fruit, maybe you need more of other nutrients than you could have for only leafy greens for example. Then you need to maybe supplement this kind of maybe phosphorous or whatever is that right?

L: 45.06 Yea and it also depends a lot on your management on the sediments on the system, if you go and re-mineralize the sediments of the system, you will have a fuller nutritional spectrum for the plants. It is very hard to do fruiting vegetables in a very small aquaponics system however when getting a bit larger then it is actually possible to go a long way with the effluent of the system. However, adding supplemental nutrients to the system if there is a lack will help both the productivity of the plant but also the uptake of the existing nutrients because there is always a limiting factors to growth of the plant.

I: 46.01 Perfect. So the last one maybe probably on this list is now to sum it up. In your own opinion, what are the most important or key aspects to consider if you have to get started for example?

L: 46.18 I think the aesthetics of the system is very important for the overall sustainability of this concept that you will be developing choosing aesthetic pleasing materials and a coherent system design will increase the enjoyment of the system and also the spread of the system …it just works better. It is also, ehh… this depends on the utility but figuring out; is this more of ornamental low maintenance system then it will probably serve as a probe for fewer classes. However, if going up so it actually has some weight of productivity then it can be more cross disciplinarian and larger part of educational material. I think it is critical also for the sustainability of a concept for an aquaponics design educational system is that you have a teaching plan that goes along with it that meets the different curriculum aspect and shows how you can work with these. Having a quite ready manual on the different courses that you could do and how to draw into different curriculum aspects would probably make it more user friendly to the teacher. And having a standardized design will also improve the spread of this because it will be easier to do it more times. let's say it is us here that needs to do it or it is something that you will be coming to do that is much easier to have good quality of the education itself if you know all the parameters throughout.

I: 48.50 Is there a concern with the winter, like you know when it's really getting cold out there for the fish? Is there like a need to warm up the containers, the tanks sorry?

L: 49.03 We want to keep the water over 5 degrees Celsius and this is primarily to sustain the microbial community and they will become dormant at lower degrees. We choose fish that are native to Denmark and so they can actually go quite low in the temperatures. Likewise, we change the production in winter time to plants that can tolerate very low temperatures. Well that being said, then increasing the temperature will increase the life of the system and the productivity. And so it is our plan to get heating into the system. We will keep the water volume for now just to keep everything healthy. But later or this spring we will be building a perfect?? stone in the bottom container to heat the air of the green houses as well but it is not a major concern. As long as you have flowing water it won't freeze and if it is indoors it is no problem, but out there yea, so it is a minor thing.

IT: 50.40 Just in general, in your opinion what do you think are the advantages and disadvantages of having a central system which is placed in the school versus a remote aquaponics system which you have here in Osramhuset? What is the implication for educational purposes?

L: 51.04 The advantage to have it at a central place is that you will be able to make an excursion with the class which will create some excitement and will relieve stress from the teacher. You have somebody who is working regularly with aquaponics and can be inspiring for the pupils. You also have a larger system or the opportunity to have a larger system than you will be able to build in the school you don't have the maintenance at the school. That is pretty much it. Then the cost is also not really there for the school and they don't need to set up any physical resources to do this on the maintenance. This is why we also built an aquaponics system for this class to take home and for this basic course we wanted to keep the maintenance and the price low. They don't pay anything now; we have the money sponsored from...so yea it is to keep all that set. The advantage to having a system in the school is that the class will be able to follow the system over longer durations. And work with a lot of different curriculum aspects in different classes or cross disciplinary with the system. It is also possible to advance from quite a basic level to a higher level year to year working with the system. It also eh it keeps the thing fresh and your mind's eye, you will be able to see the system in a regular basis. And the maintenance and the cost of the system is the major concern on supplying this to a school. However, if the school is engaging enough to actually go and invest in a system themselves then it could prove to be sustainable because then you will have to engagement from the school. If you give the system to a school, then it is more likely that it would be a bit more like a laissez-faire with the utility of the system. However, designing a forgiving system with a lower output then it could probably work okay. But it would put a bit of stress on the teachers to have some animals. But usually biology teachers already have a few biology projects going on. But I also think that biology teachers are usually some of the ones causing the most trouble. So it is also working a bit with that, how can you ensure something like that. Let's say that you combine this with a school garden, then it becomes a more integrated part of the whole school and reduce the stress from the biology teacher. But it would be nice which also broadens the understanding of the system. It could also make it possible to do a larger system with this interesting to see that you actually have some production capacity with some fish and some plants.

IT: 55.20 But in your opinion, what do you think, which system would you recommend, you think could be most practical here in Denmark which recommends those school teachers to have in remote places or like here in Osramhuse?

L: 55.39 I think both can prove to be quite good. I think the combination of having this place and maybe having a small conceptual system at the school could work out quite well. I also think that for the more engaged schools and some of them that has greener profile and a committed school is time of things a slight larger system could become very handy when the students can see that this is something that could be put to use. Then it is more inspiring and you will also be able to make some broader perspective to overall societal change and such. So a system could cost anywhere from 200kroner. however, I wouldn't suggest that, thats too small a budget, so I would say somewhere between for a very small system 800 kroner to slight larger but still more for an ornamental system 1000 to 2000kroner then you could go up to a system of maybe 5 to 10 and using that then you are quite a long way then you have 4-6sqm and a lot of fish. This thing in a greenhouse doesn't have to cost much you could do … green houses that have something like 8 to 10sqm, with an aquaponics system in it for about 15,000 to 20,000 kroner. It depends a lot on the engagement.

I: 57.50 Yea, Alright, I think we are very satisfied. Thank you for taking your time.

L: Thank you for coming today, it was very nice to have you around. I would like to see the pictures that you took as well and I am very interested to hear the feedback that you get from the teachers.

IT: I will keep you updated with that.
L: mhh.

I: 58.16 Are you going to have another class, actually where you focus again most deeply on aquaponics, the set up there?

L: 58.53 So, this was one class, I have them two times. The first time we worked only with the aquaponics system, the one that we had here and this next time they had to make their own ecosystem. However, this school was actually interested in building an aquaponics system with this program I still have six classes that can apply to come. I will be doing this classes in the start of next year. And It is possible to do an aquaponics system with one or more of these classes. However, we have a limited budget and we would need to look at if the school can invest something on their own or we can get small sponsorship.

I: 59.28 But This is the same school you say that could be interested in setting up?
L: yes
I: oh. that could be nice actually because this is in the line of what we could be like to work with a school that is deeply interested.

L: 59.40 I think that we should work out how we can at least make one of this classes have an aquaponics system in the second course that we are doing. First we are working with the one that we have here, and the next one like today when they are building something, they could be building a prototype of the system. And Depending a bit on the budget of the school what materials they already have and so on, we could do it however, I don't know how much for the design but it would be nice to go for something that could be a bit of a standardized design. However, if wanting to do just the concept as the teaching plan for the schools could get then you would make just a few components that can enable you to do it. So Let's say you can get the components for the siphon bell. Because that is a bit hard to go out and get yourselves if you don't know how to build it. so having just that one designed right then this would enable teachers that already have an aquarium and some containers at hand and a pump.

I: 1.01.04 You know what, am thinking of because actually this was our first phase of our study. Because Our project was actually about going further to implement it in a school and we are going now even to the next step of even coming up with a mini budget or something and then present it to our supervisor who is going to talk to the administration probably and see if we get funds or something like that. We are not so sure but then, let's go out there find out and let's see what comes up. Am thinking in this way maybe there could be a collaboration you know; you know the school that is interested. Is there a way maybe we can actually work it out together and find out a better system?

L: 1.01.32 If we had a budget of something like let's make it a bit nice right?
I: yea
L: and, make it a bit standardized. If we have something like 2.5 thousand or so we can make something that looks very impressive.

IT: 1.01.48 But actually, I was thinking about something, I should make this impression when I was here last time when I saw your aquaponics for the first time, you also mentioned that if schools try to implement some on the basic of aquaponics system, it demands some determination from the teacher engagement and some cost. And also the advantages of being outside or external brings the excitement for children, the fact that they travel a little bit. And it is kind of excursion you say yourself, so I don't know, maybe what do you think would be better, to invest in one place over here where you can invite a particular school, you also take the burden of the maintenance from them and you can actually develop this system here even further?

L: 1.02.42 Mmhh…We will have a greater outreach if we have somewhat a standardized design that people can take home. However, I think that the combination with going out and seeing somewhere where it is already running has a great inspirational value and you could keep it to that. That can also prove for something but it also has a benefit to take it home. And if it's something that the teachers need to engage in like you have to present it to the somebody and get the funds then you already have the engagement. So it should not be something that you force all schools to have.

IT: 1.03.20 But you think that, most of the schools you said that green schools running the school gardens project and for example they want to because you said it would be an advantage if they combined aquaponics with gardens, do you think it would be in conflict with the interest of having both aquaponics and gardens at the school or?

L: 1.03.36 No, I think it could work quite well and I think on an integrational level of having an outdoor garden and maybe a small green house then it could serve very well to have a sprouting station in a green house or in the school somewhere, where you have some fish and you have the cycle to sprout the plants that you are planting out for the outdoor.

I: Ok, tak for idag.

Children coded interview.

M – Moderator

P1 – Participant nr 1

P2 – Participant nr 2

P3 – Participant nr 3

P4 – Participant nr 4

General comments:

Children were introduced to the purpose of the interview, length and procedures before commencing the interview. Children were encouraged to participate in the focus group, but the decision in taking part in the interview were entirely voluntary. They were informed that the main language of the interview would be English, but at the same time they were welcomed to use Danish language if needed. The transcribed interview is in original language version in which conversation were conducted and translated version is included in the brackets.

Introduction :

M: Thank you very much for taking the part in the focus group session. We would like everyone to participate and do the talking, but nobody is forced to talk if does not feel like. Everyone’s opinion are important, so speak up whenever you have something to say. Please rise your hand when you want to talk and everybody will be given the chance. Remember there are no right or wrong answers and we would like to hear your personal opinions. We will be recording the session for practical reasons in order to facilitate later transcription on the paper. Nobody will be identify by name and you will remain anonymous.

M: Can anyone tell us where the food you eat comes from and how it is produced? (00:10 – 00:28)

P1: hmmmm…

P2: Det ved jeg ikke (I do not know) (*long pause and hesitation*)

M: Actually if you do not understand the question, you are welcome to ask again to repeat it. (00:28 – 00:32)

P1: ok

M: The food you eat, where do you think comes from and how it is produced? Hvor kommer maden fra og hvordan laver og producer man mad? (00:32 – 02:13)

P1: Uhhh…

P2 : Er det både grønsager og kød? (is it both vegetables and meat?)

M: Yeah, det hele (Yeah, everything)

P2: hmmm… (*pause and giggling*)

M: Yes try…

P1: Hmmm… meat comes from animals (*P2, P3, P4 giggles*)… like cows, and the vegetables comes from the seeds fra landed (from the countryside). The milk and cheese also comes from the animals… yeah.

M: Do you know where the animals are raised? (02:13 – 02:30).

P1-4: In the farm (*together*).

M: Have you ever been to a farm?

P1-4: Yeah.

M: What does healthy food mean to you? (02:33 – 03:33)

P4: Vegetables, beans hmmm… food with a lot of proteins, food which is not processed, food with no added sugars and… (*P1, P2, P3 agree*)

M: Nice, but where did you get the knowledge form, did you lean it here in the school or you learn it from your parents?

P4: I have been trying to lose weight for a long time, so I am very interested in what I eat and where the food comes from?

M: So why is it important to know where the food you eat comes from? Is it important to you? (03:38 – 04:25)

P4: For me it is important, because how the animal is treated, if they are treated bad then I am not going to eat it, because I care about the animals…

P1-3: Yeah.

P2: I like when the food is økologisk (organic)

P1: I also like when vegetables are organic because then it is free from sprøjtemiddler (spraying agents)

M: Ok, now something about aquaponics and our project we did last time. Can anyone tell us briefly what you have learned about aquaponics during that sessions? (04:25 – 05:34).

P1-4: (*inaudible quiet conversation*)

P2: You do not need lot of space to grow food and… (*pause*)

M: Do you remember how it works?

P4: Yeah, the fish gets food, and then something (*inaudible*) gets to the stones, where you have worms and plants which get the nutrients and then the water drips back again.

M: You have just mentioned some of the leaving things in the system. Could you mention it again? (05:35 – 05:55).

P1-4: Fish, worms, bacteria and… plants.

M: What do you think about the aquaponics, do you like it? (05:58 – 07:15).

P1-4: Yes

P1: I think it is good because when…. you don't have enough space to grow plants you can use the system …

P4: I think it is very good in the places where there is a war or… (*inaudiable*) (*conversation about a war picture from a middle east country they saw during previous presentation).*

M: Would you like to have and continue using aquaponics in the class? (07:17 – 07:33).

P1-4: Hmmm… (*nodding head*), Yeah… I think so… *(inaudible conversation) (pause)*

P4: If you treat it well.

M: Is there anything you may dislike about aquaponics, something that may seems to difficult? (07:34 – 07:50).

P2: Hmm….(*pause*)…No, no, no.

M: Who or what could influence you in taking an active role in caring of the aquaponics system. Are you motivated enough to take care of the system? (07:50 – 08:45).

P1-4: Hmmm… (silence).

M: Have you been appointed to any task in the aquaponics for example feeding the fish, or checking the ph levels?

P2: No…

P1: We have givet the fish mad par gange (we have fed the fish a few times).

P2: ohhh… Yeah.

M: How was it?

P1: It was fine (P1-4 giggles).

M: You already have some plants growing in the system like squash, tomatoes. How would you like to use that product that are harvested from aquaponics?. (08:47 – 09:20).

P2: You could use it i madkundskab (food knowledge class).

P1: In food classes where you could learn how to make food.

P4: You could use the herbs and learn where it comes from.

M: would you be afraid to eat it?

P1-4: No…no (*all together*)

M: Which part or component of aquaponics do you find most interesting? (09:33 – 10:10).

P4: The thing that we do not need the jord (soil) and the fish…(*inaudible*)

M: So the whole system… so, there is no special part like the fish or plant are best?

P1-4: (*all together agree with nodding the head*)

M: Of all the things we have been talking about, what is most important to you? (10:10 – 11:04).

P1: hmm…. vil du sige det igen (would you repeat)

M: Everything we have talked about, what is most important to you?

P1-4: (*silent inaudible conversation*)

MC: Just general question about the system and the way you have been using it. Are you happy with the way you are using it right now, or maybe you think that something could be done better for you to learn? (11:05 – 11:40).

P4: Yeah… if we took several tasks in it. We don't really feel that we are doing anything with this…

P1-4: Yeah

P1: Because the teachers feed the fish and maybe we could come out with the task of feeding them…

M: Or maybe make some measurements?

P1-4: Yeah

M: Thank you very much for your participation, we appreciate that.