Planet Change
Young People as Agents of Change

2.1 Educational framework



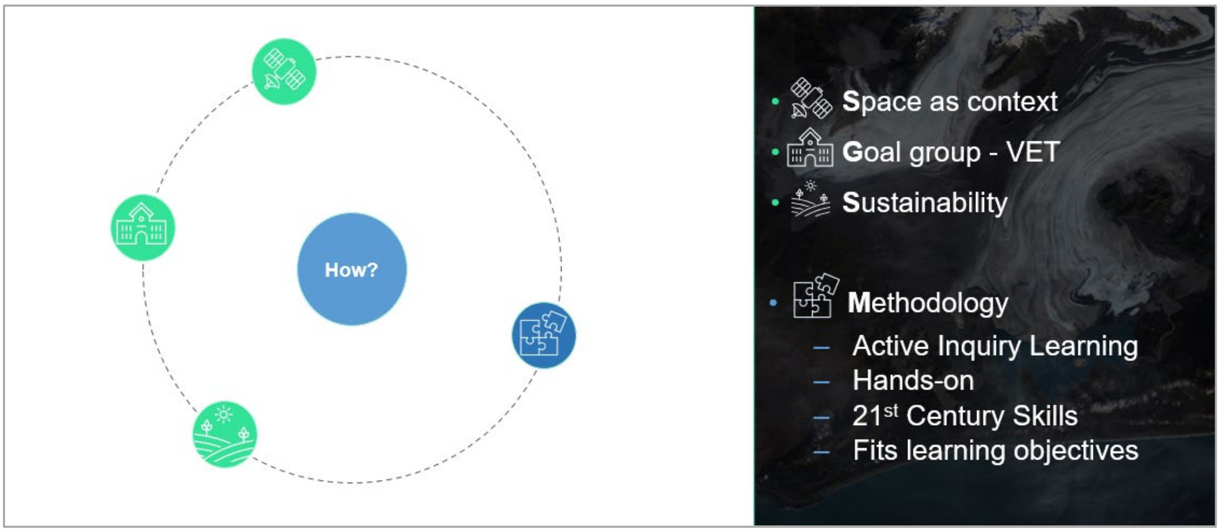
SUMMARY

The presented educational framework covers the main objectives of the project and tries to be flexible to consider the variety of learning objectives and educational strategies of VET schools. The division into phases ensures the work with the important objectives of the project, such as using the space as a context and training 21st century skills which will be applicable to several VET school cases. Phase 2 will be more oriented to a shorter range of VET schools to develop further concrete learning objectives using sustainability as a driving subject.
The educational framework can be adapted to different scenarios to suit the possibilities of the school. These range from simple case scenarios, possible to be accomplished by a teacher in the classroom using 1 session of 45 minutes, to more complex scenarios, requiring 2 or more sessions spread over different days and the collaboration of teachers of different subject areas.

Content

Educational Framework

This framework is developed for VET schools and organisations that are connected to VET education. We use space as a context, with a focus on environment and sustainability themes. In addition, the framework aims to give insight into developing activities with high qualitative learning outcomes through active-inquiry strategies, and training of 21st century skills such as communication, collaboration, creativity, and critical thinking. The framework presented is flexible and able to adapt to different kinds of learning objectives and schools' possibilities. Note that the learning objectives in VET schools are very different from school to school nationally, and even more so internationally. The educational framework drives **how** to reach these learning objectives. It is based on the following main pillars: space as a context, VET as goal group, and sustainability as driving subject, and achieve all the program goals.



Background of the Students

VET schools' learning objectives and strategies are very diverse throughout Europe, but sustainability is a rich transversal subject that can apply to several concrete cases, especially when the learning objectives are focused on hands-on learning and gaining 21st century skills. At the same time, the use of space as a context can be done in a similar way to sustainability for several resources.
The VET students we focus on are students from EU qualification level 2 and up. There is no need for pre-existing knowledge about space or sustainability.

Learning objectives

The main goal of the resources developed based on the educational framework is to reach learning objectives that fit the curricula of the VET schools all around Europe using the context introduced. These learning objectives are clearly stated in the activities. The learning activities can be downloaded from www.planetchange.eu

The learning objectives in the different activities serve as the activity goals and define what the student will be able to do after completing the activity.
The activity goals are presented in 4 groups:

- learning objectives related on the specific topics
- goals related to the activity itself, trying to strengthen the relation of the topic to VET curricula,
- training 21st century skills
- linking the topic to different career paths

Example:
Learning objectives:
The student will acquire better knowledge and training about

1. The importance of using space:
   a. How to use satellite images to monitor deforestation
   b. How to use satellite images to monitor algae bloom
   c. ...
2. How to start an environmentally friendly salmon factory
3. How aquaculture is affecting deforestation
4. Training of 21st Century skills including:
   a. Collaboration
   b. Information and media literacy
   c. …
5. How the abilities learned in the school can help to a future career in the space sector...

Sustainability and Space education

The use of satellites is very important for several aspects in our society. Using space to monitor our planet is crucial to understanding anthropogenic impacts on the environment and monitoring various parameters related to climate and climate change. In general, our daily life is highly dependent on the use of satellites. This includes helping to achieve various *sustainable development goals* (SDGs)[1]. Using space it is possible, for example, to monitor desertification, extreme weather, optimize fishing and agriculture and monitor the atmosphere. Communication and GPS systems also depend on satellites and are strongly connected to the SDGs, for example, helping to build universal education and health systems using remote access emergency services. The list grows with each new generation of satellites. Now it is possible to say that almost all the SDGs benefit from the use of satellite technology. ESA, the European Space Agency works actively towards sustainable goals. ESA provides detailed information on how ESA space programs can help with different SDGs[2].
Several online tools now provide easy access to satellite imagery, making it possible to incorporate these powerful tools into schools. Satellite images used in the classroom can provide a well-rounded

[1] https://sdgs.un.org/goals
[2] https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Space_for_Earth/ESA_and_the_Sustainable_Development_Goals

view of anthropogenic impacts around the world and can raise awareness of environmental and sustainability issues. Space is a perfect setting to complement sustainability tasks by providing easy and valuable information to analyse and discuss. This valuable information can also be used to train various 21st century skills, such as critical thinking, collaboration, and digital literacy.

Sustainability

Including sustainability and environment as part of the learning objectives of VET schools seems to be a ambitious goal to achieve. It is not easy to find direct mentions of these subjects in several curricula. However, sustainability and environment are transversal subjects that are built on content from several disciplines. There are several cases where it is possible to incorporate a sustainable perspective to enhance the learning objectives and complement the VET school curricula. In addition, this transversality offers several possibilities to develop interdisciplinary approaches, which are beginning to be central in various curricula in the EU.

Space as context

The use of space as context and, using space-based tools, can increase awareness of sustainability and environmental issues. Satellite information is a tool for increasing awareness of anthropogenic changes. By comparing satellite images one can see for example, the evolution of deforestation, the growth of desertification, and several anthropogenic changes. In addition, one can monitor disasters such as floods, forest fires, and harmful algae blooms. Google Earth Pro, EO Browser, and Sentinel Hubcan be used to gain access to satellite data in the classroom.

Image: ESA

Methodology: The five phases

The challenge of developing lesson materials for VET schools is inspiring the wide diversity of VET schools to create excitement and awareness about sustainability and space. The diversity of objectives of VET schools is extensive, but a common factor in all VET schools is that every teacher wants to inspire their students and create excitement. In the case of sustainability it is also important to raise awareness on this topic. To reach these objectives, a key factor in the methodology must be flexibility, to allow the development of adaptable resources for many VET cases. To meet these challenges, the methodology used in the resources consists of three separated phases and two additional optional phases. Each phase has its main objectives, and together they meet all the requirements expressed in the project. Phases 1 and 3 can easily adapt to many cases, while Phase 2 may depend more on the learning objectives of VET schools.

Different approaches can be developed to fit the different educational systems and curricula of the participating countries, including different levels of complexity. The following approaches are developed:

- simple case scenario, possible to achieve by a teacher in the classroom using 1 session of 45 minutes;
- complex case scenario, which requires several sessions spread over multiple days and with the collaboration of teachers from different subjects.

The second case can provide better options for training skills and an interdisciplinary approach. However, this case is more complicated to organize, especially in countries where the curriculum does not contemplate these possibilities. The first case is easier to implement.

In the annex the layout that is developed, in one of the developed activities. This layout shows the different blocks explained above. It provides a structure for important general information such as the topic, target group, duration, material background and so on.

Fig 2: Methodology, the three main phases.

Phase 1

The first phase focuses on using space as a context. Raising awareness and working with expectations are the main objectives of this first phase. The initial phase starts with assessing the expectations and of the students on this topic. It is important to have the expectations clear before starting with the second phase: working on the actual topic in the challenge.

Students will collaborate by analysing the first piece of information that will drive the task. This can be seen as the motivation for continuing with the core of the activity and using satellite data. The main goal is to raise awareness of a particular environmental or sustainability issue and reflect on the possible reasons behind it. This phase is also suitable for starting to work with 21st century skills, for example by using expectations analysis questions to encourage discussion in working groups.

For example, comparing satellite images of the Amazon taken recently and a few decades ago to see how the rainforest is vanishing. This is very easy to do with online tools like Google Earth Pro and works very well for raising awareness. Students can work in groups and discuss fundamental questions together such as: Who is responsible? How much is my country involved in this situation? What can be the consequences if that continues? What can we do?... These questions can generate a good debate, reflections, and exchange of opinions, actively working with some 21st century skills.

Phase 2

The second phase is the main core of the activity. This largely depends on the learning objectives of the VET school. It consists of practical activities and questions to understand what students are doing and it involves active inquiry scenarios. This phase can include taking measurements, building devices, making calculations, searching for additional information on the Internet, and more. In general, the student must be an active actor in the process. The strategy of this main body of the task can be very different from one resource to another, reflecting the differences between the curricula of VET schools.

The second phase is intended to be completed in the classroom or lab. However, for some VET schools, outdoor activities may be an even better fit for learning objectives. This may be the case for activities related to agriculture or aquaculture, but it will largely depend on the capacity of the VET school to organize such events.

Phase 3

The third phase focuses on training 21st century skills. This can be achieved by working in groups to analyse information, discuss the findings and build the final conclusions. Reflection and discussion scenarios driven through questions will be central. A comparison with the questions of the first phase is valuable in several cases. Questions to trigger the exchange of opinion are important, as well as to analyse how it is possible to contribute to improve sustainability and/or environmental issues.

Phase 4 (optional)

In this section it is important to focus on the space career orientation for VET students. By presenting extra information on future career opportunities students are able to link the different topics to their daily world. Students can use this info in their future and relate to the different opportunities in the space industry and the use of space related tools for their future jobs.

Phase 5 (optional)

Excursion: This section describes how the teacher can complement the activity with an excursion, in ex. to an industry and/or institutions related to space activities and/or sustainability. These visits can help to reinforce the idea that working in the space sector is also a possibility for the VET students, and to see and discover future opportunities in the sector.

Example, main phases 1-3:

Phase 1: Satellites' eyes help from Space

…This task makes use of satellite images to see changes in the forest on our planet Earth... Use Google Earth Pro and analyze the changes in the rainforest in Rondonia from 1980 to 2022...

Work in groups, talk together about the following questions. After exchanging opinions, write your conclusions:

- Analyze what you see.
- What do you think is the new use of the land?
- What countries do you think are mainly responsible for deforestation in Amazonia?
- …

Phase 2: Feeding salmon, how to do it environmentally friendly?

Activity - In this case for aquaculture (subject in the VET farmer school in Norway). This can focus on starting a simple viability study (business case) to grow salmon in an aquaculture center. It may include tasks like looking on internet for different ways how this is done, make calculations of costs for different types of food (proteins), investigate the origin of the food, make a simple business plan based on this…

Phase 3: Reflection and next steps

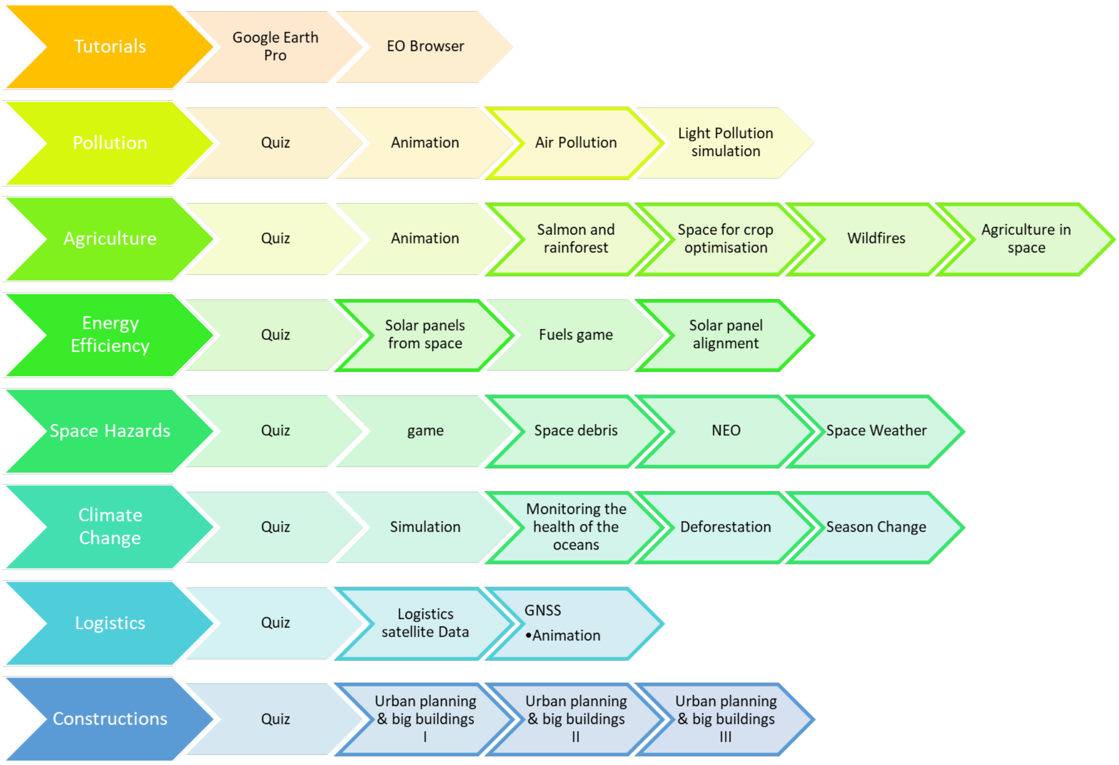
… after going through the activity, go back to the question of the first section. Work in groups, talk together again about these questions and what you have found out. Write your final conclusions and discoveries.

In addition, discuss together what we can do to develop a more environmentally friendly production of salmon…

Fig 3: Methodology, the three main phases goals

Activities

The activities developed are combined in 6 different topics. Each topic starts with a quiz to spark the interest of the students on that subject. Some of the topics also have a general animation to explain the topic, a simulation to try and experience or a game for fun. Per topic different lessons are developed. The bold line indicates the lessons developed. Without the bold line, these are online extra resources.



Topics on space and sustainability

Pollution

Light pollution is a real problem, as its effect on behaviour of animals. We need light to feel safe, but there is an importance for sky darkness preservation for astronomy and consequently for the positive aspects astronomy brings to sustainability. Collaterally, the negative effects light might have in our health and in the lives of animals. Not having access to the night sky has implications for the population: enjoying the view of the milky way in its full greatness, is something that can bring us back in contact with nature, and make us realize how amazingly beautiful nature can be. Knowledge about air pollution is important because it impacts the health of our lives. In the activity we focus on the differences between the different generations as well as how we can make air pollution visible using astronomy tools.

Agriculture

The main problems of today and the near future are combined in the 27 sustainability goals. Many of those goals such as poverty, hunger, good health and climate change are connected to agriculture. Knowing how to influence agriculture can help the planet.

For example, fish farming is a possible factor contributing to the deforestation in Amazonia. Students will go through different sources to explore this correlation. They will analyse the origin of the food used for fish farming and make calculations of the forest area needed for salmon production. Finally, they will search for more sustainable ways for this important sector.

Also, wildfires are another factor in the context of agriculture. Low Earth Satellites (LEO's) can be used to study wildfires.

Energy Efficiency

The burning of fossil fuels contributes significantly to climate change. Aims to educate students about the global fuel system and its impact on society, politics and the environment. By understanding the importance of sustainability and renewable energy sources, students will be inspired to design their career and future choices.

Solar panels are important for renewable energy. How are these installed, how do you orient those to optimize the energy and make them as efficient as possible. What roofs are optimal to choose for solar panels.

Space Hazards

A consequence of space exploration is the space debris that exists. In the challenges, the students explore the topic of space debris. What are the current dangers, what is its reduction and what is currently done to prevent or clean up debris.

Climate Change

Stopping climate change is one of the 27 sustainability goals. We can use satellite data to monitor and understand how global warming is of influence on the planet. For example, the decrease of the amount of sea ice and how this may be changing important ocean currents. The consequences can be significant, not only accelerating global warming itself, but also affecting weather patterns in large areas of the world, especially Europe.

As part of climate change we also want to raise awareness about the problem of deforestation, and its prevalence and extension, in order to counter the common belief that forest destruction is something which is happening very far away. We aim at making young people realise that this is a problem that we all share, by engaging them with the problem of deforestation in their own countries and reflecting on ways to minimise it. Deforestation has many causes, several of them related to human action (such as excessive urbanisation, diets relying on animal products, and certain professional activities).

Logistics

Under the topic of Logistics, we focus on GNSS and satellite data. GNSS is developed in the theme of space as an instrument to measure distance. Originally for military purposes, but nowadays it is used
by

everyone. The topic of logistics therefore consists of two sub-topics. GNSS and how to get the satellites data. Students learn how GNSS works.

Constructions

In the topic of construction we raise awareness about environmental and urban degradation, encourage sustainable urban preservation and refunctioning and raise awareness of the use of biodegradable materials such as leftover foods. Students map abandoned and dismissed structures and buildings using satellite data. In this way they recognize the impact of abandoned spaces on the urban context on a social, economic and environmental level.

Teacher Training

To get acquainted with the materials a training about the activities is recommended. The main goal of such a training is to

- get to know the different activities
- learn about the topics
- get familiar with the methodology and the tools

It is recommended to organise a training with a minimum of three times half a day.

1. An (online) session to get familiar with the used online satellite data tools
2. A session on site to play with the activities and learn with and from each other
3. An (online) session to reflect on the activities.

In half a day not all activities can be tried out, but getting a good idea of the activities is possible. For the first online session the developed tutorials for the EO browser and Google Earth Pro can be used. For the on site session it would be best to try out as many activities as possible. It can be helpful to ask the teachers to prepare the activities before the start of this session and to ask the teachers to read the different teacher manuals. For this second part the session duration can be easily longer than half a day. For the last session it is open to the teachers how this half day can be introduced. Either the session can be used for the teachers to reflect on the activities and discuss the activities with each other, or it can be a more guided session for the teachers to get even more information about the different topics.

Planet Change will produce both tutorials and webinars to use for both guided online sessions as well as private online sessions for teachers who would like to know more about the topics on their own. All resources can be downloaded at www.planetchange.eu

Annex – Layout of the activities

PLANET
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Agriculture in Space: constructing a hydroponic system

Teachers manual

Co-funded by the
Erasmus+ Programme
of the European Union

Planet change is the short name of an EU Erasmus+ project aimed at VET teachers and their students. With small activities, the idea is to create awareness about sustainability and acquire 21st century skills. All this is done in a technical context, mostly from space technology.

www.planetchange.eu

Contents:

1. General information

Duration: 2 or 3 lessons in total, including one activity

Target group: 16-20 y.o.

European qualifications framework level: 1-4

Teacher preparation: study background information, materials listed with the activity

Topic

Themes: space hazard, construction, agriculture, climate change

Keywords: innovation, sustainability, engineering, life support systems

Activity

Goals
After this activity, students have a better understanding of the benefits hydroponic farming may offer, and its usage for extra-terrestrial farming. Students are able to construct and set up a hydroponic culture.

Summary
In these lessons, students will construct a hydroponic (soilless) culture, in which they grow crops. First, they get to learn and understand different conditions in space and the basics of hydroponic systems. With that knowledge, they can construct their own system.
Of course, conditions in space are also different, apart from the lack of nutritious soil. For students to understand this can add to the depth of their understanding, but it is not necessary to go into details here. Just a basic understanding that creating a closed ecosystem is required, will suffice.
Next, the students learn what different types of hydroponic systems exist and which variables they can change or manipulate to successfully grow crops. For this, it is necessary to understand what conditions they can vary and what challenges they have to overcome in constructing a functioning system.
The nutrients should probably be an already existing mix, in order to be able to focus on the experiment itself.
After the benefits and drawbacks are discussed, the actual experiment can be done, where they make their own hydroponic culture.
Once the system is constructed and the crops are fed, they will need some time to grow.
N.B.: if this is just a technical challenge, with constructing a closed system and making it work, there is no real need to wait for the crops to grow.
After a week (or more), the crops can be harvested. Depending on the time there is and the level of experience, you can choose to analyse the results. At least, there should be some of the crops that have grown and are ready to harvest.
Finally, there can be a discussion about the benefits and drawbacks of hydroponics.

2. Introduction

What if we want to have a spaceship in an orbit around the moon, or even Mars (which is the ultimate goal of the Artemis-mission)? How will those astronauts be able to feed themselves? It won't be possible – or at least, very inconvenient – to supply them regularly.
So, we will probably be aiming at an ecosystem inside the spaceship, or maybe even on the surface of the Moon or Mars, where they can grow and harvest vegetables.
There are already sealed ecosystems inside space stations, but how do you keep it small and efficient? This can be very complicated and might take a lot of materials that need to be sent (in)to space.
One of the solutions to diminishing the latter, is to grow crops without soil; a so-called soilless or **hydroponic culture**. This means no soil to transport, but also less space needed and even options to grow crops vertically (on Earth, that is). There are various ways to do this, and some agricultural companies are already doing this on Earth. For usage on Earth, there are also a lot of benefits; less materials are needed, less space is needed, more control over various conditions, etc.
But for space, it looks like the only sustainable way to create an ecosystem. Thus, NASA is also testing this in space (CELSS, see link below).
Obviously, we will not be able to test in space, but we can discuss what effects different variables have. And, the principles are the same; what is tried and tested on Earth, seems to work similarly in space.
Therefore, most of the research done on the subject is done on Earth and slightly adapted when put to use in space.
What we want to do here, is look at the benefits and drawbacks of hydroponic farming and construct our own system, in order to get a grasp of the technological opportunities (and challenges) there are when building a hydroponic system in a spaceship (apart from the lack of gravity).

Description of the activity

The activity itself consists of constructing a hydroponic culture. Depending on (the level of) the classes, a decision has to be made beforehand how far you want to take it; is it more about construction, more on agriculture, or are both equally important?
The (optional) schedule will thus look like this:
Lesson 1: Introduction about ecosystems in space, discussion and reflection; introduce hydroponics, including variables
Lesson 2: Decide which variables to test, construct hydroponic system, 'insert' crops
Lesson 3: Harvesting; results and discussion*

*: if you want to actually grow crops, that is

Note that the actual activity is lesson two; this means that there will be no practical part in the first lesson if you choose not to plant/start a 'control system'.
For ideas on approaching the subject more interactively, there are some triggering questions added after the first lesson.

3. Lesson 1

Introduction to agriculture in (semi-)closed ecosystems (15 min)

What is an ecosystem and why is it important to understand how it works? Why do we want to build ecosystems in space? What differences are there between growing crops on Earth and in space? How can you control ecosystems, and what factors do you have to take into account?

Optional: Start a culture (10 min)

In order to get results, it is advised to 'prepare' some crops, so the students will be able to collect results about a week after lesson 3. So, in the last part of this lesson the students will plant some seeds, under 'normal' conditions, to have crops to insert in the system. Be aware that you have to be able to 'separate' them later on. Make sure you have enough crops to be able to compare, for example 2*3=6, 3 in both systems.

Introduction to hydroponics (25 min; seen Annex II for information)

What different types of hydroponic systems are there? Which would work in space (and which wouldn't)?
Explain what kind of system they are going to construct and which drawbacks and benefits there are to that system.
Decide which variables they want to vary (possible variables: nutrient fluids, fluid volume and flow rate).
Make a rough sketch / idea of the system.

Suggestions for activating questions / considerations, both about hydroponics and about farming in space:

- Why does a seed sprout 'upwards'?
- Does (the lack of gravity) influence the firmness of the leaves?
- Does the lack of gravity mean that crops grow in random directions?
- What extra measures do you have to take when doing this in space?
- How can you make it even more sustainable / circular?

4. Lesson 2

What variables to vary, and how (20 min)

Look into the different possible variables, and decide which one to control (for instance, two small hydroponic systems, with different flow rates. Or one regular, soil-based system). This will be essential to know before constructing the hydroponic system(s) and starting it.
Explain about the nutrient solution, let the students think of a way (or several ways) to mix it.
Make sure there is a 'control group'; the hypothesis should exist of expected differences and/or similarities between systems. One system doesn't give much data on HOW the systems function, if they do seem to produce proper crops.

Construction of a hydroponic system (25 min)

After the decision has been made on what nutrients and flow rate(s) to use, the actual construction can start.
For each individual plant, you will need a pot. Which have to be fitted into the PVC pipe. So, drill as many holes as you need to place all the pots in the tube. Be sure that: the pots are tight in the system; the roots of the plants can soak the water/nutrient solution.
Place a reservoir for the nutrient fluid, connect the pump to the system and to the reservoir.
Install the pump, make sure the system is watertight.
After you have made sure all is sealed properly and the plants are able to drink the nutrient fluid, the experiment can start. Fill your reservoir with the nutrient fluid, turn on the pump and check whether all is working properly.

5. Lesson 3

Harvesting and collecting (25 min)

If you have decided to grow crops and analyse them, now is the time to collect.
After a week (or more) of growing your crops, you can harvest them.
Be sure to remind the students of the differences between the systems and the hypothesis they had about the (possible) different outcomes that would generate.

Suggestions for ‘measuring’ / comparing the crops:

- Size of the leaves
- Sturdiness
- Colour
- Development of the roots
- Nutrients (if possible to measure)

Reflection/discussion (20 min)

What have the students learnt? Were there some surprises along the way? What was the most (and least) challenging part? What would they do differently? And what the same? Any ideas on different research?

6. Reflection

After the experiment, students can discuss the benefits and drawbacks of hydroponics, or at least of the hydroponic system they constructed. Also, there will probably be some technical challenges and (im) possibilities they ran into.
In conclusion, they should have an idea about the dos and don’ts when considering a hydroponic culture (in space).

Connections with the industry, career paths and possible excursions

As stated before, several agricultural companies already use and/or test hydroponic cultures on Earth. With a shortage of materials, a limited amount of space to grow crops and the soil getting less fertile and dryer, this is getting increasingly interesting to investigate for companies.
Therefore, a lot of research is being done and this will probably expand over the coming years.
In most EU countries, there are places to visit and experts to be consulted (or maybe invite them to explain a bit). Denmark, Italy and the Netherlands all have large facilities.
In Spain, it is particularly big in the Almeria region, in Portugal there is one near Lisbon, but also on Tenerife, in Norway in Spitsbergen and Oslo.

7. Annex I: Materials

PVC pipe (not too slim)
Pump (a simple pump for a garden pond should be fine)
Reservoir for the nutrient fluid
Post to put the plants in (n.b.: these must fit IN the PVC pipe)
Nutrient solution for a NFT system (this is commercially available)

8. Annex II: Background information / tutorials / examples

Hydroponics

What is a Hydroponic Farming System?
The Latin word hydroponics means “working water”. Hydroponic farming is the method of cultivating plants without using soil.
In this farming technique, water replaces soil, such that water delivers nutrients to the plants.
So, instead of exerting energy on looking for nutrients in the soil, the crop’s roots can focus on their growth because the nutrients are easily accessible.
As a result, plants can grow quicker and healthier.
In traditional farming, plants need soil to provide water and nutrients, but it is unnecessary during the photosynthesis process.
So, as long as there’s water and nutrients, plants can sustain themselves and survive.

This is mostly done by using water-based mineral solutions:

- Water culture (soilless culture); just water and nutrients to feed plants (or with peat-based, rockwool, coir, perlite, …)

Types of water cultures: Nutrient film technique (NFT), deep water culture (DWC), aeroponics (a.o.)

Terrestrial or aquatic plants may grow with their roots exposed to the nutritious liquid or in addition, the roots may be mechanically supported by an inert medium such as perlite, gravel, or other substrates. Because there is an inert medium, these are called soilless cultures.

Types of soilless cultures: ebb and flow, wick systems, Dutch bucket, bag culture (a.o.)

Different types of hydroponic systems

1. Deep Water Culture System
A deep water culture system or DWC system is the easiest method in hydroponic farming because it lets water aerate the plants. This system is currently the most popular method in the market.
In this system, the netted pots holding the plants are directly in deep water. This submerges plant roots and help the plant’s access to nutrients.
2. Wick System
The Wick system is where you need to use a growing tray to hold the plants. Then, you need to place the tray on top of a nutrient solution container.
Instead of a pump, you simply connect a wick from the growing tray to the reservoir.

With the help of capillary action, the wick will absorb water and nutrients from the container. Then, it transfers the nutrients to your plants.
This system is especially suitable for novices since the wick constantly waters your plants, even if you are away.

3. Nutrient Film Technique System

In this system, netted pots are placed within channels in which water is continuously allows to flow over the roots of the plants.
The channels are tilted to allow the water to flow easily. And it needs an aerated such as air stone and water pump to let the water travel upward back to the channel.
Unlike the deepwater system, the nutrient solution of the NFT system flows over plant roots.
However, you will need to change the water and nutrients every week. This is to ensure that your plant receives enough nutrients, to keep the water clean and avoid the build-up of algae.
This system would likely fit large-scale farming or commercial scale because it can be easily expanded.

4. Ebb and Flow System

The unique thing about an ebb and flow system is its timer. A water pump starts filling the grow bed with the nutrient solution from the container below.
When the timer stops, the water slowly drains back to the reservoir underneath.
To control the water, the grow bed is equipped with an overflow tube. This prevents the stem and fruits from getting wet.
This method suits any vegetation because it imitates or even perfects the natural periodical cycle of rain and drying and makes faster plant growth possible.

5. Drip System

This system is also one of the most popular methods among commercial growers. It allows the nutrients to pump to slowly drip into the tube of individual plants, which keeps them well-nourished.
The drip system comes in two different configurations.
Firstly, there is the recovery system, which is popular among amateur home growers. It circulates water to the plants and drains it back to a reservoir.
The other configurations are so called non-recovery systems, which are famous amongst commercial growers. After the plants have absorbed the nutrients, the remaining water drains off through a tube and becomes waste. Therefore, it is convenient to plant large crops like melons, onions, pumpkins, and zucchinis.

6. Aeroponics

Aeroponics is also a unique way of doing hydroponic farming. With aeroponics, farming can be done vertically (i.e., like a tower) or horizontally (like a cube).
It allows the plant to suspend in the air and expose its roots to nutrient solutions.
Nutrients are pumped from a reservoir where a nozzle delivers the solution in a fine mist to the plants.
The mist is usually sprayed from the top and cascades down to the chamber for a vertical type.
Because of its vertical setup, this system consumes 95% less water than traditional methods and is very suitable in situations where there is limited ground area.

Benefits of hydroponics

When it comes to growing hydroponically, these systems offer a variety of benefits over other plant production practices. Such benefits associated with hydroponic systems include higher rates of production, improved crop quality, lower water usage, reduced area required for production, and the potential for year-round production at just about any location. Thus, these systems can be quite profitable, making them desirable for both hobbyist and commercial growers alike!

… key benefits compared to soil culture including the fact that the roots of the plant have constant access to oxygen and that the plants have access to as much or as little water and nutrients as they need. This is important as one of the most common errors when cultivating plants is over- and underwatering. Hydroponics prevents this from occurring as large amounts of water, which may drown root systems in soil, can be made available to the plant in hydroponics, and any water not used, drained away, recirculated, or actively aerated, eliminating anoxic conditions in the root area. In soil, a grower needs to be very experienced to know exactly how much water is needed to feed the plant. Too much water, and the plant will be unable to access oxygen, which can lead to root rot; too little water causes the plant to undergo water stress or lose the ability to absorb nutrients, which are typically moved into the roots while dissolved, leading to nutrient deficiency symptoms such as chlorosis.

Why grow without soil?

- Grow anywhere
- Fewer resources
- ‘Easy troubleshooting’ (less variables)

Benefits of hydroponic culture:

- Conserves water
- Maximizes space
- Facilitates micro-climates
- Grows crops faster
- Nutrient control
- Produces higher yields
- Produces fresh and high-quality food
- Time saving, cost effective
- Easy harvesting
- And… no soil needed

Drawbacks of hydroponics

Drawbacks:

- Expensive setup
- Dependence on electricity
- Needs constant monitoring and maintenance
- Risks of waterborne diseases
- Problems affect plants quicker

Common problems:

- System clogging
- Infestation (algae, pest)
- Seedling problems (wilting, dead roots)
- Nutrient deficiency (tip burns)

Nutrients

What fertilizer do I need for hydroponics?

The typical 3-part fertilizers used in general hydroponics are NPK (Nitrogen, Phosphorus, Potassium) fertilizer mix, $CaNO_3$(Calcium Nitrate), and $MgSO_4$(Magnesium sulphate).

While commercial farmers mainly use powdered fertilizers, home growers mostly prefer liquid fertilizers because they are easier to dose.

Can you use regular fertilizer for hydroponics?

Yes, you can use regular fertilizer for hydroponics.

However, regular fertilizers lack some nutrients needed by hydroponic plants, which can cause problems at different growth stages.

Therefore, it is best to use products purposely made and tailored for hydroponic farming.

Macronutrients

Nitrogen

This nutrient is an essential amino acid element responsible for your plants' faster growth and development.

Phosphorus (P)

It is the nutrients responsible for photosynthesis, growth, and fruiting for plants that bears fruits.

Potassium (K)

This nutrient is essential, especially for fruiting plants, because it helps grow stems, roots, and flowers, maintains pressure, releases waste gases and vapor, and prevents wilting.

The other macronutrients like Calcium (Ca), Magnesium (Mg), and Sulphur (S) also help plants grow and photosynthesize.

Micronutrients

Nutrients like Boron (B), Zinc (Zn), Manganese (Mn), Iron (Fe), Copper (Cu), Molybdenum (Mo), and Chlorine (Cl) are also essential for nurturing and development of plants.

These things are all critical for your plant's growth. So, what fertilizers are best with the complete nutrients your plant needs?

You can choose between these three types:

Powdered Fertilizers

This type is a dry fertilizer usually used on a commercial scale. You can easily use it by following the instructions and dissolving it with water.

It comes in different Nitrogen, Phosphorus, and Potassium ratios, or what we usually call NPK.

However, the ratio depends on what plant you're planting. For example, the proportion of NPK for lettuce is different from tomatoes.

The disadvantage of this type is that it is pricey, especially the premium ones.

Liquid Fertilizers

This type of fertilizer is the easiest way to deal with because it only needs a little preparation. It dissolves faster than the powder.

However, if you buy it in distant places, the shipping will be costly because it's liquid. And it is more expensive than the solid type.

Organic Fertilizers

Organic fertilizers or homemade fertilizers are one of the most budget-friendly options.

It is from natural resources. However, preparing the different ingredients is challenging to make the nutrient solution needed.
All nutrients should be from a partially decomposed material.
In using organic fertilizer, expect that more water consumption is needed because you need to change the solution frequently to avoid odour formation.
It would be best if you control the amount of nutrients solution. And compared to processed fertilizers, it slows the growth of plants.

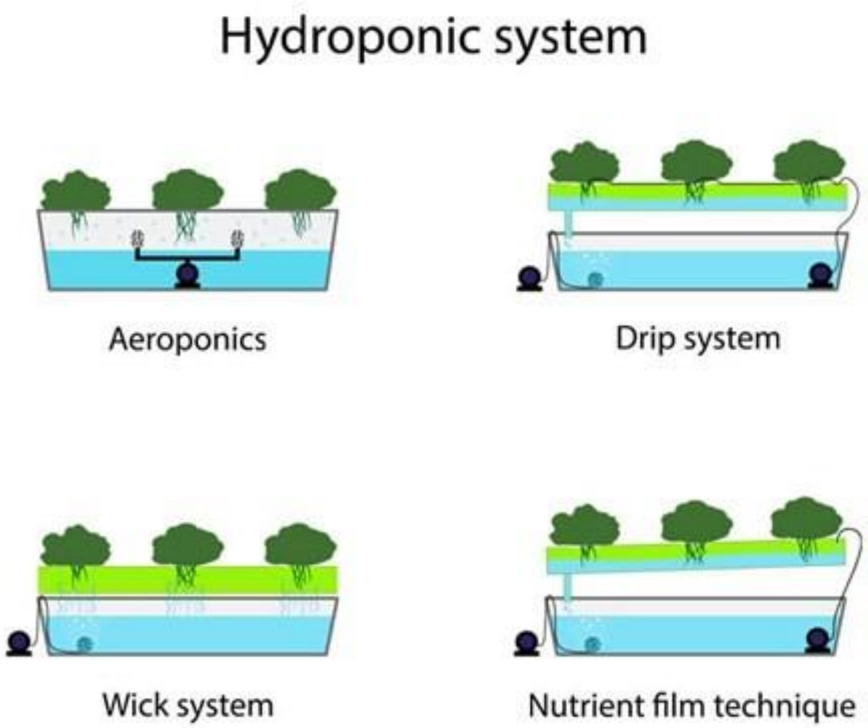
Further information / background:

https://www.nal.usda.gov/farms-and-agricultural-production-systems/hydroponics
https://en.wikipedia.org/wiki/Controlled_ecological_life-support_system (on NASA research)
https://en.wikipedia.org/wiki/Hydroponics

Building instructions:

how-to-build-hydroponics-unit-pvc-pipes-cheap-veggies-soilless-farming
https://www.instructables.com/PVC-Hydroponics-Unit/

9. Annex III: visualisation of hydroponic systems




WHAT IS HYDROPONIC FARMING?
BEGINNER'S GUIDE
WHAT IS HYDROPONIC FARMING SYSTEM?
Hydroponic farming is the method of cultivating plants without using soil
Types of Hydroponic Farming System
Deep Water Culture System
Wick System
Nutrient Film Technique
Ebb and Flow System
Drip System
Aeroponics
WHAT IS VERTICAL HYDROPONIC FARMING?
It is a way of stacking up several layers of farm space on top of one another in a vertical direction
How does vertical hydroponics work?
With the help of high-powered pumps
This compact design is space-saving and efficient
CROPS THAT YOU CAN GROW IN A VERTICAL HYDROPONIC TOWER
ADVANTAGES AND DOWNSIDES OF HYDROPONICS
BENEFITS
Conserves water
Maximizes space
Facilitates micro-climate
Grows crops faster
Nutrient control
Produces higher yields
Does not require soil
Produces fresh and high-quality food
It doesn't need pesticides
Time-saving and cost-effective
Easy harvesting
DISADVANTAGES
Expensive setup
Dependence on electricity
Needs constant monitoring and maintenance
Risks of waterborne diseases
Problems affect the plants quicker

Colophon

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