



Educational pack for FOOD 2030 Interactive Exhibition

D5.2: Educational pack for FOOD 2030 Interactive Exhibition
WP5 - T5.2

Authors: Sofoklis Sotiriou, Katerina Riviou (EA)



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

Technical references

Project Acronym	CLEVERFOOD
Project Title	Connected Labs for Empowering Versatile Engagement in Radical Food system transformation
Project Coordinator	Christian Bugge Henriksen University of Copenhagen cbh@plen.ku.dk
Project Duration	January 2023 – December 2026 (48 months)

Deliverable No.	D5.2
Dissemination level*	PU
Work Package	WP5 – Schools and Youth Education
Task	T5.2 - Deploy the interactive FOOD 2030 Science Education toolkit
Lead beneficiary	11 (EA)
Contributing beneficiary/ies	CVIVA
Due date of deliverable	31 December 2024
Actual submission date	31 December 2024

- * PU = Public
 PP = Restricted to other programme participants (including the Commission Services)
 RE = Restricted to a group specified by the consortium (including the Commission Services)
 CO = Confidential, only for members of the consortium (including the Commission Services)

v	Date	Beneficiary	Author
1.0	24/09/2024	EA	ToC – Katerina Riviou
2.0	09/11/2024	EA	Sofoklis Sotiriou, Katerina Riviou (V1)
3.0	27/12/2024	EA	Sofoklis Sotiriou, Katerina Riviou (final)
4.0	29/05/2026	EA	Sofoklis Sotiriou, Katerina Riviou (final, revised based on comments from review)



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

Executive summary

This deliverable presents the Educational Pack for the FOOD 2030 Interactive Exhibition, developed to support awareness, engagement, and learning around sustainable food systems in line with the European Commission's FOOD 2030 policy framework. The educational pack is designed to translate complex research and policy concepts into accessible, interactive learning experiences for diverse audiences, including citizens, students, educators, and stakeholders. It accompanies the FOOD 2030 exhibition and enables participants to better understand key food system challenges and solutions.

The pack aims to:

- Enhance understanding of FOOD 2030 priorities (nutrition, climate, circularity, innovation, communities).
- Facilitate interactive and experiential learning through guided activities.
- Support educators and facilitators in delivering engaging content.
- Encourage behavioural change and critical thinking around food systems.

The educational pack is built on:

- A learner-centred and participatory methodology, ensuring accessibility for non-expert audiences.
- Integration with the interactive exhibition layout, linking content directly to exhibition elements.
- Modular design, allowing flexible use in classrooms, workshops, or informal learning settings.

The pack includes:

- Educational modules aligned with exhibition themes
- Activity sheets and facilitation guidance
- Supporting materials explaining key concepts
- Tools to stimulate reflection, discussion, and action

The educational pack is intended for use in:

- Schools and universities
- Public exhibitions and science outreach events
- Policy engagement and stakeholder dialogues

It can be adapted to different target groups and settings, ensuring scalability and long-term impact.

The educational pack contributes to:

- Bridging the gap between research, policy, and citizens
- Increasing visibility and uptake of FOOD 2030 initiatives
- Supporting food system transformation through education



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

Glossary of Key Terms

FOOD 2030	EU policy framework aimed at transforming food systems towards sustainability, resilience, and inclusivity
Food System	The interconnected network of activities involving production, processing, distribution, consumption, and waste
Sustainability	Meeting present needs without compromising future generations, across environmental, economic, and social dimensions
Circularity	A system where resources are reused, recycled, and minimised to reduce waste
Bioeconomy	Use of renewable biological resources to produce food, materials, and energy
Interactive Learning	Educational approach involving active participation and engagement rather than passive consumption
Stakeholders	Individuals or groups involved in or affected by food systems (e.g., farmers, consumers, policymakers)
Co-creation	Collaborative process of designing solutions involving multiple stakeholders
Food Environments	Physical, economic, political, and socio-cultural contexts influencing food choices
Behavioural Change	Shifts in individual or collective habits towards more sustainable actions
Open school	Educational approach that actively connects schools with their surrounding community, enabling students to learn through real-world experiences, collaboration, and engagement with societal challenges.
Educational Pathway	Structured sequence of learning experiences, activities, and resources designed to guide learners progressively toward specific knowledge, skills, or competencies.
Learning Ecology	A Learning Ecology is the physical, social, and cultural context in which learning takes place



Table of Contents

Technical references	2
Executive summary	3
Glossary of Key Terms	4
Table of Contents	5
List of Figures	7
List of Tables	7
1. Introduction	8
1.1 Scope	8
1.2 Target Audiences	8
1.3 Information about the Exhibition	8
1.4 Structure	15
2. The CLEVERFOOD Pedagogical design: Educational Pathways in the CLEVERFOOD Context	16
2.1 Developing Learning Ecologies	16
2.2 Pedagogical Principles for the Design of Educational Pathways in the Framework of CLEVERFOOD Exhibition	18
2.3 The Driving Forces of the proposed approach	20
2.3.1 Rethinking How Schools Work	20
2.3.2 Shift from Students as Consumers to Creators	21
2.4 Context of Implementation: Characteristics of the Open Schools	21
2.5 Design Features of the CLEVERFOOD Educational Pathways	23
2.6 Supporting Schools to become Sustainable Innovation Ecosystems	24
2.7 Viable Change: Sustainability as a route to the future	25
2.8	25
Practices for implementation	25
Empowering students as learners	26
Contextualise knowledge so it is coherent	26
Connect learning to real issues and settings	26
Extend learning beyond the school	26
Inspire students by customising learning experiences	27
Use technology in service of learning	27
2.9 Key Conditions Supporting the Development of an Open Schooling Culture	27
Establish a learning culture	28
Create shared responsibility for student learning	28
Establish a culture of trust and professionalism	28
Preserve time for teachers to collaborate	28
Resource-Based Learning and Use of Unique Open Educational Resources	28
Components of resource-based learning	28
Enabling contexts	29
Resources	29



D5.2 Educational pack for FOOD 2030 Interactive Exhibition	6
Tools.....	29
3. Indicative Educational Pathways	31
3.1 The Environmental Impact of Tomatoes: From Farm to Table	31
How do we assess the Environmental Impact of Tomatoes?	31
What Are the Land Requirements for Tomatoes?	32
What Is the Water Footprint of Tomatoes?	33
What Is the Agrochemical Usage for Tomatoes?	34
What Is the Carbon Footprint of Tomatoes?	35
What Is the Waste Generation of Tomatoes?	36
How Can You Reduce Your Environmental Impact and Offset Your Personal Carbon Footprint?	36
Final Thoughts	38
3.2 You Can Grow Tomatoes from Seeds That Flew in Space!	38
What does the program involve?	38
Why grow tomatoes in space?	39
Collecting and Recording Your Data	39
Keeping a class record	39
4. Conclusions.....	42
Annex A: the CLEVERFOOD Educational Pathways Templates... 	43
The concept of Educational Pathway	43
Educational Pathways user roles and use contexts: Defining the dimensions of digital-resource-based science learning	43
The Educational Pathway Patterns	45
Structure of the Educational Pathway Patterns	46
The Educational Pathway Patterns developed	47
Educational Pathway Pattern for a Pre-Structured Visit by the School Community	47
Educational Pathway Pattern for an Open Visit by Lifelong Learners	52



List of Figures

- Figure 1: The organisation of the content of the CLEVERFOOD Exhibition (lesson plans, videos, interactive tools) in the form of Educational Pathways across the different thematic areas will give opportunities for the presentation of the development of projects and activities, connected with the major challenges we are facing. The visitors will be able, starting from an exhibit to explore the key thematic areas through a continuous interaction between theory and experimentation. 9
- Figure 2: A graphical representation of the Learning Ecology that describes the learning paths of individuals in the framework of school and out-of-school science learning activities..... 17
- Figure 3: The CLEVERFOOD Exhibition aims to raise students' awareness on the importance of sustainable food systems by providing scientific for the current status. Different visualization techniques, based on scientific data can be used to present the issues described by the specific exhibit. For example, one can demonstrate the land-use demands for meat-based and non-meat-based diets of the population (here the case of Copenhagen is presented). In this way students are introduced in the scientific methodology by making hypothesis, defining parameters, analyse data and reflecting on the results. 20
- Figure 4: A graphical representation Modelling and Growing Learning Leadership. Source: OECD/UNICEF (2016): What makes a school a learning organisation? A guide for policymakers, school leaders and teachers, p.8..... 27
- Figure 5: The CLEVERFOOD Exhibition will be enriched with numerous digital resources forming Educational Pathways that will engage students in related and interconnected activities. Through the proposed contextualised approach, the hypothesis, the instruments used, the observations will be presented in a form of a storyline that will help the visitor to realise the key challenges for the future food systems..... 30

List of Tables

- Table 1: An overview of the exhibits, the relevant areas and the topics. 11
- Table 2: The main Pedagogic Principles and the Educational Objectives for the design and implementation of the CLEVERFOOD Educational Pathways..... 18
- Table 3: Components and Characteristics of Resource-Based Learning (RBL) 29
- Table 4: Contexts of use of the CLEVERFOOD service..... 44
- Table 5: Contexts of use, user roles, and user independence 44
- Table 6: Educational Pathway Patterns and user groups..... 46



1. Introduction

The aim of Task 5.2 is to design and deliver the interactive FOOD 2030 Interactive Exhibition toolkit that is expected to facilitate the deployment of the FOOD 2030 Interactive Exhibition across Europe by organising teacher trainings, summer schools, webinars and workshops with teacher trainers, embedding learning materials on specialised platforms (like OSOS and Scientix), and applying recorded materials to develop and run a MOOC. Training will be framed as a process of transforming learning environments to be integrated in local communities in line with the principles of Open Schooling, by forming Educational Pathways that crosscut different learning contexts. The educational pack forms the reference document for the FOOD 2030 Interactive Exhibition that describes the guiding principles and the overall pedagogical approach of CLEVERFOOD while it provides templates for the design of educational materials that can enrich the visitors experience either in structured educational pathways or in more open free choice educational visits.

1.1 Scope

This document describes the overall educational approach adopted for the development of the educational pack for the FOOD 2030 Interactive Exhibition.

1.2 Target Audiences

The main audience of the CLEVERFOOD exhibition and overall educational approach described in this document are defined according to their roles as potential visitors of the exhibition as follows:

- *Teachers*: schoolteachers wishing to integrate the use of such resources in their teaching.
- *Students*: school students who may use such resources either as part of their curricular learning, or in out-of-school learning (e.g. in free time or with family).
- *Science museum educators or science communication professionals*: Staff who prepare science learning or awareness raising experiences for the visitors/users of their institutions (science museums and centres). An additional subgroup here might also be other professionals too related to science communication, including journalists who may search for content relevant to the promotion of informal science learning.

1.3 Information about the Exhibition

The Food2030 Exhibition is composed of 11 Exhibits, and its layout is organised into four main areas:

- The entrance area, **Foodology**, explores the role of food in shaping identities, communities, and cultures.
- **Happy Food** follows, highlighting the impacts of our dietary choices on health, society, and the environment.
- **Act for the Future You Want** provides strategies and alternatives for transforming the food system towards fairness, sustainability, and health.
- Finally, the central area, **The Power is in Our Plate**, encourages visitors to reflect and take action for positive change.

Table 1 presents an overview of the exhibits, the relevant areas as well as the topics.



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

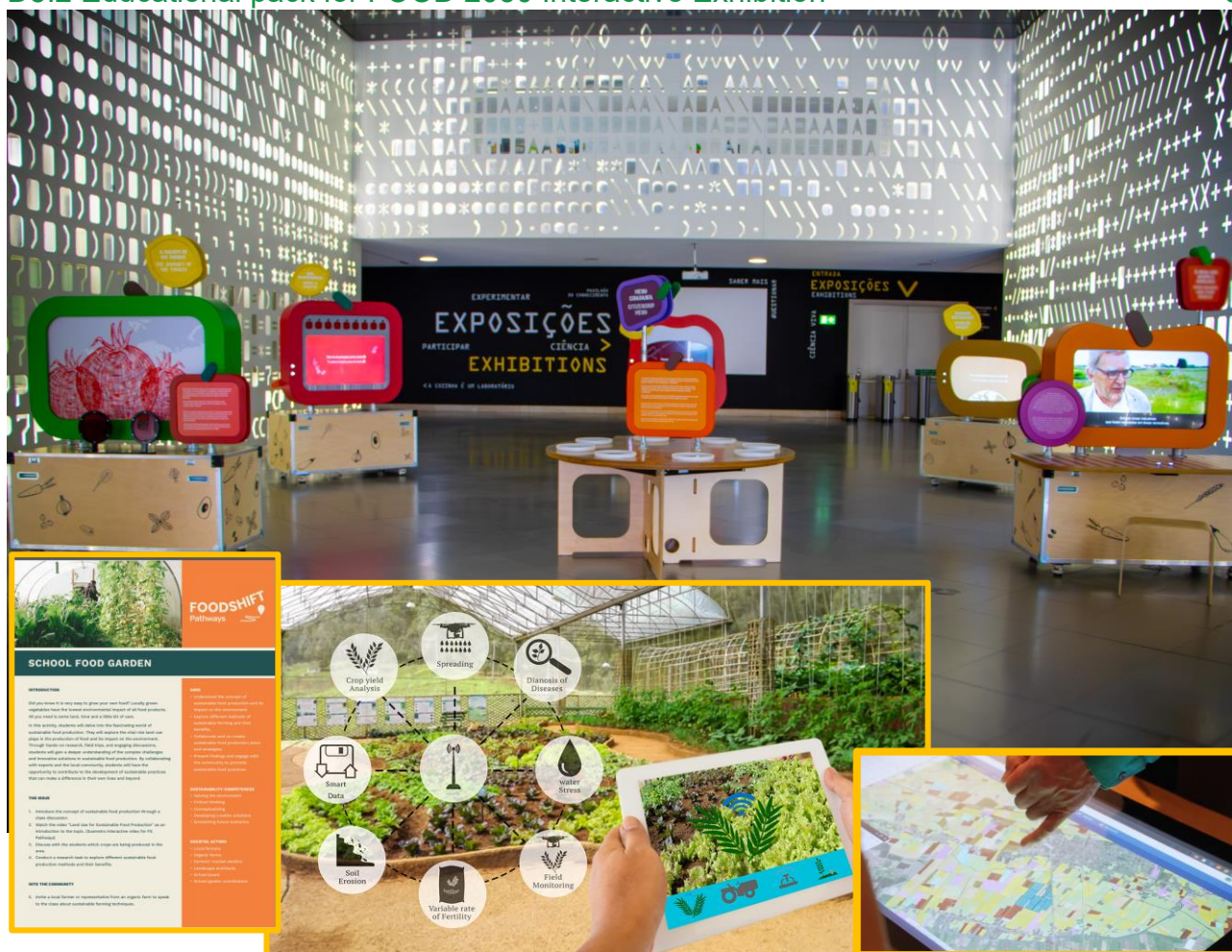


Figure 1: The organisation of the content of the CLEVERFOOD Exhibition (lesson plans, videos, interactive tools) in the form of Educational Pathways across the different thematic areas will give opportunities for the presentation of the development of projects and activities, connected with the major challenges we are facing. The visitors will be able, starting from an exhibit to explore the key thematic areas through a continuous interaction between theory and experimentation.

The current document forms an integrated educational package (methodology, pedagogical approach, templates for the creation educational activities related with the exhibition) that can be used during the training events that will be organised in the framework of the project. Furthermore, it proposes the design of virtual visits to the exhibition through the interactive application hosted in the project website (<https://food2030.eu/exhibition/>).

We are proposing the design and implementation of educational pathways for the exploration of the different themes of the exhibition. The concept of Educational Pathway in CLEVERFOOD reflects the priority given by the project to responding to the needs of the diverse communities of potential visitors of the CLEVERFOOD exhibition. Thus, an Educational Pathway describes the organisation and coordination of various individual learning resources into a coherent plan so that they become a meaningful science learning activity for a specific user group (e.g., teachers, students, other museum visitors, etc.) in a specific context of use. Such an approach holds a great potential to explore the key themes by enriching the exhibits with additional resources and materials (Figure 1) to meet the needs of the different target groups.

In this context, we are proposing a generic framework for the design, development, implementation and evaluation (both short and long term) of educational activities that can be used to introduce the sustainable food systems related issues and the principles of Responsible Research and Innovation in school classrooms.



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

The aim of the CLEVERFOOD consortium is to formulate a common set of guidelines and recommendations on how scientific work and findings in the field can be used to provide an engaging educational experience through the exploration of “real science”. Research on learning science makes clear that it involves development of a broad array of interests, attitudes, knowledge, and competencies. Clearly, learning “just the facts” or learning how to design simple experiments is not sufficient. To capture the multifaceted nature of science learning, we are proposing a roadmap that includes a series of “Pedagogic Principles for the design of the Educational Pathways” and articulates the science-specific capabilities supported by the environment of the open school.

The CLEVERFOOD approach puts emphasis on creating viable change to school settings that lasts and expands. It aims to demonstrate how current challenges that our society is facing could form the basis for the design of innovative educational projects for school communities. The CLEVERFOOD exhibition forms a unique reference point for the introduction of the theme of sustainable food systems to school curricula. Teachers have the chance to design (using the proposed templates) a variety of short- or long-term projects of different levels of complexity to raise students’ awareness to these major topics.

Through an extended training program that will be offered through numerous channels (workshops, webinars, MOOC) we expect to form a network of innovative practitioners who are ready to share their experiences with others. It is built on numerous national and international initiatives and provides a unique resource for a school reform towards a more effective school environment. Thinking about the future or even performing isolated experiments is not enough for decision makers in education. It is also necessary to conceptualize how to change current systems in specific powerful ways. System thinking in action addresses sustainability and the need to change context. How do contexts or systems change? They do so over a very long period. System change evolves because of major alterations in demographics, technology, and other social forces. But we want to accelerate the development of good changes like the spread of professional learning communities. The key to this involves conceptualizing sustainability and using leadership to change context or the environment by a) increasing leaders’ participation in wider contexts and b) helping to develop leadership in others so they can do the same. Our training sessions will highlight these issues along with the concepts of Open Schooling and Resource Based Learning in an evolving educational landscape.



Table 1: An overview of the exhibits, the relevant areas and the topics.

Exhibit	Area	Photo	Key message	Short Description	Themes	Indicative Resources
A feasty planet	FOODOLOGY		Our relationship with food is not only physical but also emotional and social. This exhibit serves as an inviting and immersive introduction to the exhibition, engaging visitors in a playful and sensory manner.	This exhibit features a hallway with two immersive murals showing food-related social scenes. Through audio and photos, these murals guide visitors into the exhibition, highlighting the significant role food plays in our lives.	Significance of role food plays in our lives; traditional food products	The safeguarding of culinary and dietary traditions UNESCO: Intangible Cultural Heritage related with food
Food poll	FOODOLOGY		Why we eat what we eat. A mural invites visitors to vote on why we eat what we eat and to reflect on the collective outcome.	In this participative exhibit, visitors vote on their main motivation to eat by placing a coloured sticker on a voting wall. Each colour denotes a different motivation category. This process allows individual and collective choices to be visible.	Dietary behaviours, eating together	Food choices Current Opinion in Behavioral Sciences: Social influences on eating WebMD: Why we eat the foods we do
Planet on a plate	HAPPY FOOD		The exhibit informs visitors about the impact of our current food system on the environment and the reciprocal effects of environmental degradation on food systems. By showcasing the intricate connections between the food system, ecosystem harm, and climate change, the exhibit prompts visitors to reflect on the environmental implications of their food choices.	This exhibit features an infographic panel that vividly illustrates various issues related to food sustainability and environmental harm.	Food system impact, environmental degradation, biodiversity loss, ecosystem	The environmental impact of food system Our World in Data: Greenhouse gas emissions across the food chain Our World in Data: Greenhouse gas emissions of food Chatham House: Food system impacts on biodiversity loss PNAS: The environmental impact of food products

This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

The journey of a tomato	HAPPY FOOD		The exhibit offers a unique exploration of the extensive distances food travels before it reaches our tables.	The visitor encounters a world map illustration that appears monochromatic. When using specialized filters, distinct routes—both short and long—emerge in contrasting colours. By manipulating the filters, they reveal hidden details that illustrate the diverse paths various foods, such as tomato, soy, bananas, rice, sugar, cocoa, coffee and oranges take across the globe.	Food miles; foodprint, The impact of food transportation; local food; short supply chain; Local and traditional products	Food transportation Our World in Data: Food miles by transport Our World in Data: Food choice vs eating local
We are all connected	HAPPY FOOD		When it comes to food, if we look closely, we can see that we are all connected. The exhibit illustrates the intricate web of activities, production factors, and stakeholders involved in food production, using products made from maize as examples.	This exhibit features a panel with four buttons on the left side, each representing a distinct food product: Corn cobs, animal feed, popcorn, and cornflakes, as well as 16 nodes symbolising the activities and stakeholders involved in food production within the food system. When a visitor presses one of these buttons, the connections between the nodes and the corresponding pathways light up sequentially on the panel. This visualization the journey of the selected food product through the network of points, highlighting the roles played by various actors in its production and distribution.	Food system actors/stakeholders	Coffee production Mauch Chunk Coffee Co.: The journey of coffee Fairtrade Foundation: Coffee farmers Stakeholders involved in food production EIT Food: A day in the life of...

What a waste	HAPPY FOOD		Food waste from farm to fork: the exhibit exposes the widespread issue of food waste throughout the entire food supply chain, as well as in our homes.	Food waste from farm to fork: the exhibit exposes the widespread issue of food waste throughout the entire food supply chain, as well as in our homes.	Food waste; Zero waste; Biomaterials; organic food scraps; Transform Leftovers; Imperfect food; Composting	Food loss and waste UNEP Food Waste Index Report 2024 Key Messages World Economic Forum: Fish and seafood waste
Tasty menus	HAPPY FOOD		A balanced diet is essential for our health and that of the planet. This exhibit raises visitors' awareness of the importance of a balanced, plant-based diet, not only for health but also for the planet.	A scenography of a giant mouth is "fed" by the visitor with "dishes" that simulate food products. Inside, a screen provides not only information about the impact to our health of the chosen product, but also the impact to the planet: CO ₂ emissions, water consumption and soil occupation. The results presented are based on a comparison between the products.	Plant based meals, Organic Food.	Healthy diet World Health Organization: Healthy diet
Worlds apart	HAPPY FOOD		This exhibit highlights inequality in access to food and water, food insecurity and to give voice to the basic right to available, affordable and adequate food for all.	The exhibit features a large screen where the visitor watches a short video exposes different aspects of food access inequality.	Food security; food desert	The impacts of food industry Food Empowerment Project: Food deserts Food Unfolded: What impact does the food industry have on our health?
Food heroes and food rebels	ACT FOR THE FUTURE YOU WANT		This exhibit showcases projects and people who work every day to create a healthier, sustainable, and fair food system.	The screen will play testimonial videos of individuals and projects dedicated to transform the food system. The videos play in a random sequence, keeping the experience fresh and informative for as long as the visitor remains seated.	Food innovation;	Food Apps SISTERS project Greenhouse agency

Clever kitchen	ACT FOR THE FUTURE YOU WANT		This exhibit highlights inequality in access to food and water, food insecurity and to give voice to the basic right to available, affordable and adequate food for all.	This exhibit features a vertical totem with engaging visuals and illustrations designed to invite interaction. Each side of the totem represents a different area of the kitchen, with buttons, doors, drawers, and shelves that serve as interaction points, representing places and equipment such as drawers, fridges, cupboards, and cookers. These interaction points reveal informative texts and graphic content.	Food security; seasonal food; local produce; Food storage; compost	Food storage EUFIC: Food storage in the fridge Seasonal food EUFIC: Seasonal fruit and vegetables in Europe Composting National Geographic: How to compost at home
Citizenship menu	THE POWER IS IN YOUR PLATE		The visitor is challenged to greater civic and social participation by contributing to a fairer, healthier, and more sustainable food system. A round table with eight seats invites participants to move closer and to discover a suggestion of civic participation.	A table invites the visitor to explore ways to contribute for the change of the food system. In each plate, the visitor finds a sentence that describes an action. The visitor is challenged to choose one of eight, as a compromise for the future.	Fair food, healthy and sustainable food system; plant-based food	Food literacy Nutrition Reviews: Food literacy in children and adolescents Plant-based food in Europe GFI Europe: Market insights on European plant-based sales CORDIS: The growth of European plant-based food industry

1.4 Structure

The document is organised in the following core chapters.

Chapter 2 describes the methodology adopted for the design of the educational package. By capitalising on the concept of Learning Ecologies, it describes the pedagogical principles for the design of the Educational Pathways and the expected learning outcomes for the students. It presents their key features and the context of their implementation. Here the expected contribution from the open schooling environment is analysed. the guiding principles and the conditions that must be in place for the proposed methodology to be implemented are also presented. The chapter highlights the key conditions that school heads must have in mind if they want to embark their schools in the transformation journey.

In **Chapter 3** we present two indicative Educational Pathways that are related to the “Journey of a Tomato” exhibit. The exhibit offers a unique exploration of the extensive distances food travels before it reaches our tables. The first pathway is based on numerous scientific data and archives related with the ecological footprint of the tomatoes. A full analysis is presented along with the data sources. The aim of this pathway is to introduce students to an in-depth investigation and study of all parameters that have an impact on the ecological footprint of a commonly used vegetable. The second pathway describes a long-term project that engages students in real scientific processes that teach and reinforce inquiry skills, while they explore concepts related to plants, space, careers, nutrition, and agriculture.

Chapter 4 concludes the deliverable and describes its expected role in the training activities of WP5.

Annex A acts as the guidebook for the design of the Educational Pathways. The design template of the Educational Pathways integrates the key features of the project’s approach; based on the model of inquiry learning that has been adopted to support both virtual and physical field trips but also field trips across different museums and science centres.



2. The CLEVERFOOD Pedagogical design: Educational Pathways in the CLEVERFOOD Context

2.1 Developing Learning Ecologies

To understand and value the world we live in, we need to learn about science. We need scientific knowledge and skills to give meaning to information, to value it, to solve problems, to make educated decisions, and to take advantage of opportunities. Without the ability to critically evaluate information, scientific concepts can be misunderstood, and pseudo-scientific reasoning can mislead people. Therefore, we should help students develop the necessary dispositions and become informed citizens capable with others to use science and technology wisely to solve the numerous global problems humans now face. Formal schooling is one way in which people can learn about science. It is organised and guided by formal curricula with the focus on the acquisition of domain knowledge and scientific skills leading to a formal accreditation such as a diploma or certificate.

An even larger part of science learning, however, takes place out-of-school. It results from daily activities related to family or leisure. In most cases, it is guided by curiosity or interest and leads to enjoyment. People learn in diverse places, as they grow up, for instance within their families, their communities, through the media, in after-school programmes, in the street, while they travel, and while they visit places like museums and science centres. Sometimes, they learn about the same concepts and phenomena in different learning contexts. As a result, an important question arises: Do these people integrate the same concepts and phenomena which they learn in these different contexts, and if so, how? While some research shows that people create links between different learning contexts^{1,2}, most of the literature points to a serious lack of contact between formal and informal learning contexts that are introducing the same concepts and phenomena^{3,4}. As out-of-school learning experiences become more common in people's lives (considering the increased number of informal science learning initiatives available), it is crucial to inquire about and better understand how science learning outside the classroom influences them. Such an inquiry process could start by providing valid and systematically evaluated answers to a series of questions such as:

Why are out-of-school learning activities so motivating? Do they also lead to more positive attitudes towards science? To what degree, if any, do they influence people's knowledge and skills? And if not, can these activities be adapted in such a way that they do? How do they relate to formal schooling and how might activities from both contexts complement or strengthen each other? And can informal science learning activities be used to support people in acquiring a scientific way of thinking, so that they can understand and correctly use all scientific information to which they are exposed? Could out-of-school activities support the open schooling strategy of the EU, where schools in cooperation with external stakeholders share the responsibility for student learning?

¹ Eshach, H. 2007. Bridging In-school and Out-of-school Learning: Formal, Non-Formal, and Informal Education. *Journal of Science Education and Technology* 16, 171–190.

² Fallik, O., Rosenfeld, S. and Eylon, B. (2013). School and Out-of-School Science: A Model for Bridging the Gap. *Studies in Science Education*, 49:1, 69-91.

³ Kim, M. & Dopico, E. (2016). Science education through informal education. *Cultural Studies of Science Education*, 11, 439-445.

⁴ Leonard, S. N., Fitzgerald, R. N., Kohlhagen, S., & Johnson, M. W. (2017). Design principles as a bridge between contexts: From innovation in the science museum to transformation in formal education. *EDeR. Educational Design Research*, 1(1). <https://doi.org/10.15460/eder.1.1.1059>



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

On the one hand, there is a vision for opening the school⁵ (EU, 2016)⁶ to new learning experiences and to new partnerships with external stakeholders that promote student learning. Arguably, such experiences may enhance students' motivation and interest for the subject. On the other hand, due to the pressure that educational policy guidelines and requirements place on school performance, it is questionable whether out-of-school places of learning are really integrated in such educational policy strategies, as there are no standardized processes in place to assess their potential impact on student learning.

These developments in out-of-school science education and in formal education seem to offer a unique opportunity to bridge the gap between the two worlds by developing an appropriate catalysing process: A **connected science learning ecosystem** where youth may encounter a wide range of learning experiences and be supported by adults and peers in ways that could lead to future opportunities in personal, academic, professional, and civic realms. This is a vision that requires educators and organizations to think beyond the bounds of their own institutions to consider how collective action at the level of networks can provide opportunities and address inequalities in a way that more isolated efforts cannot. When discussing how youth might thrive in such an ecosystem—and what sort of interventions we can develop to help all youth do so—the idea of pathways⁷ has often come up as a useful metaphor that invites us to consider youths' "learning lives" over time and across the many contexts (e.g., home, school, community organizations, science centres and museums, web and social media) where learning may occur.

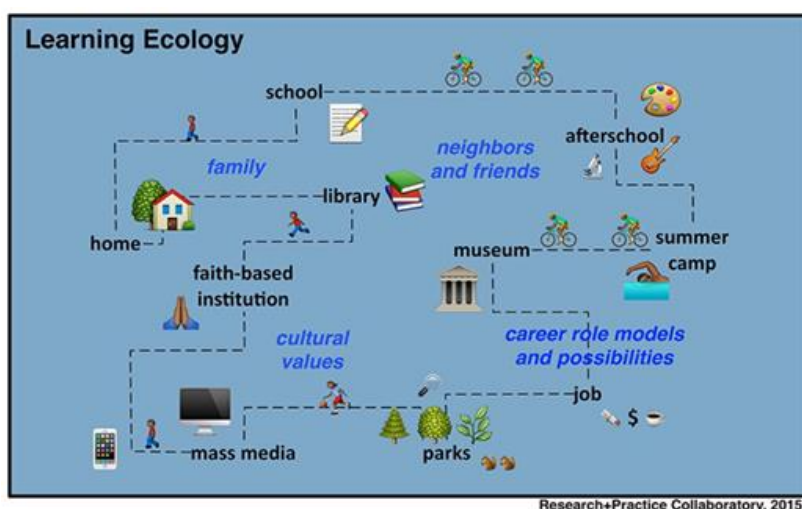


Figure 2: A graphical representation of the Learning Ecology⁸ that describes the learning paths of individuals in the framework of school and out-of-school science learning activities.

A **Learning Ecology** is the physical, social, and cultural context in which learning takes place. Like natural ecosystems, learning ecologies (see Figure 2) have physical dimensions, which may or may not include easy access to nature, science museums, or advanced science programmes or internships. However, we are less used to thinking about the sociocultural dimensions of learning ecologies. Learning ecologies are the contexts—the physical settings, social interactions, value systems and histories—in which people learn over time, both daily and during the lifespan. Robust science learning ecologies, like their counterparts in nature, are characterized by diversity, redundancy, and local adaptations. This means that a robust science learning ecology contains a wide variety of programmes, across a range of institutions and places, allowing youth different and multiple ways to engage with science. In this framework, individuals take increasing levels of ownership over their own learning as they grow older and gain more experience. Several collaborative partnerships and networks are being created to optimize opportunities across a range of institutions and

⁵ <https://www.openschools.eu/>

⁶ Hazelkorn, Ellen & Ryan, Charly & Beernaert, Yves & Constantinou, Costas & Deca, Ligia & Grangeat, Michel & Karikorpi, Mervi & Lazoudis, Angelos & Pintó, Roser & Welzel-Breuer, Manuela. (2015). Science Education for Responsible Citizenship. 10.2777/12626.

⁷ Sotiriou, S., Bybee, R., & Bogner, F. X. (2017). PATHWAYS – A Case of Large-Scale Implementation of Evidence-Based Practice in Scientific Inquiry-Based Science Education. *International Journal of Higher Education*, 6(2), 8–17. <https://doi.org/10.5430/ijhe.v6n2p8>.

⁸ <https://www.nsta.org/connected-science-learning/connected-science-learning-march-2016/stem-learning-ecologies>



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

organizations (see for example the Open Schools for Open Societies partnership of institutions of formal and informal learning <https://www.openschools.eu/>).

2.2 Pedagogical Principles for the Design of Educational Pathways in the Framework of CLEVERFOOD Exhibition

To explore the idea of Learning Ecologies for the development of Educational Pathways across the CLEVERFOOD thematic areas and capitalizing on the project exhibition we propose a generic framework for the design, development, implementation and evaluation (both short and long term) of educational activities that can be used to introduce the sustainable food systems related issues and the principles of Responsible Research and Innovation in school classrooms. This framework builds on a four-strand model developed to capture what it means to learn science in school settings by adding two additional main strands incorporated for informal science learning, reflecting a special commitment to interest, personal growth, and sustained engagement that is the hallmark of informal settings.

Table 2: The main Pedagogic Principles and the Educational Objectives for the design and implementation of the CLEVERFOOD Educational Pathways.

Strands – Pedagogic Principles	Educational Objectives
Sparkling Interest and Excitement	<i>Experiencing excitement, interest, and motivation to learn about phenomena in the natural and physical world.</i>
Understanding Scientific Content and Knowledge	<i>Generating, understanding, remembering, and using concepts, explanations, arguments, models, and facts related to science.</i>
Engaging in Scientific Reasoning	<i>Manipulating, testing, exploring, predicting, questioning, observing, analysing, and making sense of the natural and physical world.</i>
Reflecting on Science	<i>Reflecting on science as a way of knowing, including the processes, concepts, and institutions of science. It also involves reflection on the learner's own process of understanding natural phenomena and the scientific explanations for them.</i>
Using the Tools and Language of Science	<i>Participation in scientific activities and learning practices with others, using scientific language and tools.</i>
Identifying with the Scientific Enterprise	<i>Coming to think of oneself as a science learner and developing an identity as someone who knows about, uses, and sometimes contributes to science.</i>

These Pedagogic Principles provide a framework for thinking about elements of scientific knowledge, innovation and practice. This framework describes a series of support functions that must be deployed for the long-term impact of the proposed activities to be safeguarded. Such support actions could include support for: the integration and coordination of educational and outreach activities between groups across different research institutions; the science community and scientists interested in educational and outreach activities; the education communities interested in scientific content and applications; special events and activities that provide means and tools for web-based communication and collaboration. This framework provides a useful reference for helping teachers and outreach groups in the informal science education community articulate learning outcomes as they develop programs, activities, and events, and further explore and exploit the unique benefits of introducing scientific research in schools. Furthermore, such an action asks for knowledge areas integration, effective and closes cross-institutional collaboration, and organizational change in the field of science education. In the following we are presenting the key issues related with the proposed strands in more detail.

Sparkling Interest and Excitement

The motivation to learn science, emotional engagement, curiosity, and willingness to persevere through complicated scientific ideas and procedures over time are all important aspects of learning science. Recent research shows that the emotions associated with interest are a major factor in thinking and learning, helping



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

people learn as well as helping them retain and remember. Engagement can trigger motivation, which leads a learner to seek out additional ways to learn more about a topic.

Understanding Scientific Content and Knowledge

This strand includes knowing, using, and interpreting scientific explanations of the natural and physical world. Students who are visiting science centres and museums, research infrastructures and other science related places come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science. Students also must understand interrelations among central scientific concepts and use them to build and critique scientific arguments. While this strand includes what is usually categorized as content, it focuses on concepts and the link between them rather than on discrete facts. It also involves the ability to use this knowledge in one's own life. Effective outreach programmes and on-line labs could provide great tools for the teachers who must cope with an increased number of student's questions on complex topics related with scientific research.

Reflecting on Science

The practice of science is a dynamic process, based on the continual evaluation of new evidence and the reassessment of old ideas. In this way, scientists are constantly modifying their view of the world. Students reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena. This strand also includes an appreciation of how the thinking of scientists and scientific communities' changes over time as well as the students' sense of how his or her own thinking changes. Research shows that, in general, people do not have a very good understanding of the nature of science and how scientific knowledge accumulates and advances. This limited understanding may be due, in part, to a lack of exposure to opportunities to learn about how scientific knowledge is constructed and how scientific work is organized. It is also the case that simply carrying out scientific investigations does not automatically lead to an understanding of the nature of science. Instead, educational experiences must be designed to communicate this explicitly.

Using the Tools and Language of Science

The myth of science as a solitary endeavour is misleading. Science is a social process, in which people with knowledge of the language, tools, and core values of the community come together to achieve a greater understanding of the world. Even small research projects are often tackled by teams of researchers. Through participation in informal environments, non-scientists can develop a greater appreciation of how scientists work together and the specialized language and tools they have developed. In turn, students also can refine their own mastery of the language and tools of science. Using the tools of science, such as scientific archives combine with satellite data in a game-like approach to estimate the land-use demand resulting from meat consumption and non-meat consumption diets for a certain population sample, students could become more familiar with how scientists work on their research problems. By engaging in scientific activities, participants also develop greater facility with the language of scientists; terms like hypothesis, experiment, and control begin to appear naturally in their discussion of what they are learning. In these ways, non-scientists begin to enter the culture of the scientific community.



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

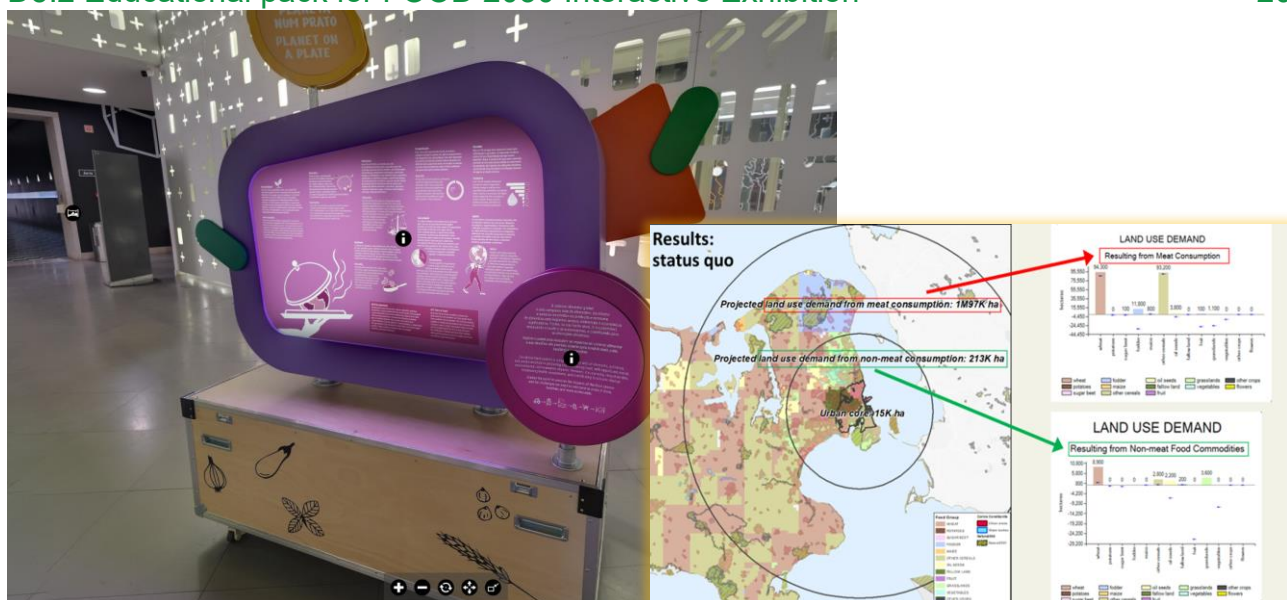


Figure 3: The CLEVERFOOD Exhibition aims to raise students' awareness on the importance of sustainable food systems by providing scientific for the current status. Different visualization techniques, based on scientific data can be used to present the issues described by the specific exhibit. For example, one can demonstrate the land-use demands for meat-based and non-meat-based diets of the population (here the case of Copenhagen is presented). In this way students are introduced in the scientific methodology by making hypothesis, defining parameters, analyse data and reflecting on the results.

Identifying with the Scientific Enterprise

Through experiences in the framework of outreach and educational programmes, some students may start to change the way they think about themselves and their relationship to science. They think about themselves as science students and develop an identity as someone who knows about, uses, and sometimes contributes to science. When a transformation such as this one takes place, young people may begin to think seriously about a career in a research field, in an engineering firm, or in a research laboratory. Changing individual perspectives about science over the life span is a far-reaching goal of outreach and educational activities of the major research infrastructures. Sustaining existing science-related identities may be more common than creating new ones.

2.3 The Driving Forces of the proposed approach

2.3.1 Rethinking How Schools Work

There is a focused movement to reinvent the traditional classroom paradigm and rearrange the entire school experience — a trend that is largely being driven by the influence of innovative learning approaches. Methods such as project based and inquiry learning call for school structures that enable students to move from one learning activity to another more organically, removing the limitations of the traditional timetable. The multidisciplinary nature of these contemporary approaches has popularized the creative application of technology and fostered innovative designs of school models that link each class and subject matter to one another. As learning becomes more fluid and student-centered, some teachers and administrators believe that schedules should be more flexible to allow opportunities for authentic learning to take place and ample room for independent study. Changing how learning takes place in classrooms is also requiring shifts in the business models of schools, which are increasingly becoming more agile and open to trying new approaches.



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

This trend is largely a response to the overly structured nature of a typical school day, which some believe hampers learning. Traditionally, bells have signified the beginning and end of each day, ushering students from one class to the next. In many ways, the bell symbolizes the separation of disciplines, making a clear statement that each should be kept disparate. In the past few years, many teachers have made progress toward bolstering interdisciplinary learning, also commonly referred to as integrated studies. Edutopia describes this model as combining “curriculum from two or more disciplines, allowing students to see how ideas are connected.” They point to collaboration, critical thinking, and knowledge retention as three positive outcomes for students. Technology use is at the heart of this design as activities such as integrating 3D printing in science classes and media production into humanities courses become more pervasive.

The goal is for students to understand the various intersections between different subject matter, acquiring a skillset that is desired in the contemporary workforce.

2.3.2 Shift from Students as Consumers to Creators

A shift is taking place in schools all over the world as students are exploring subject matter through the act of creation rather than the consumption of content. A vast array of digital tools is available to support this transformation in K-12 education; indeed, the growing accessibility of mobile technologies is giving rise to a whole new level of comfort with producing media and prototypes. Many teachers believe that honing these skills in learners can lead to deeply engaging learning experiences in which students become the authorities on subjects through investigation, storytelling, and production. Other components of this trend include game development and making, and access to programming instruction that nurtures learners as inventors and entrepreneurs. As students become more active producers and publishers of educational resources, intellectual property issues will become a key component of K-12 curricula. There is growing support for empowering learners as creators that demonstrate their mastery in forms that surpass traditional tests and worksheets. Emerging instructional frameworks are encouraging teachers to use digital tools that foster creativity along with production skills. This trend also implies that teachers are increasingly becoming creators, too, and are therefore in the position to lead activities that involve developing and publishing educational content.

2.4 Context of Implementation: Characteristics of the Open Schools

In the framework of the project the participating schools will be supported to set forward an innovation agenda that will help them to:

- Promote the collaboration with non-formal and informal education providers (science centres, museums and scientific foundations), parents and local communities to ensure relevant and meaningful engagement of all societal actors with science and increase the uptake of science studies and science-based careers, employability and competitiveness. With the focus on science learning in both primary and secondary education level the CLEVERFOOD innovation agenda proposes new and diverse models of collaborations between the above-mentioned stakeholders. By building on the best of current practice, the proposed approach aims to take us beyond the constraints of present structures of schooling toward a shared vision of excellence. Such an innovation programme holds great potential. If we want a powerful and innovative and open culture in schools that is self-sustaining, we must empower system-aware practitioners to create it, whilst avoiding simply creating interesting but isolated pockets of experimentation. We must instil a design-based approach of collaborative learning and inquiry between professional practitioners, thus creating a “pull” rather than “push” approach. To promote such an approach in the current schooling practices, an ecosystemic standpoint should be taken from the side of the remedying initiatives. More specifically, the latter should aim to capture the profiles, needs, contributions and relationships of all these school-related actors and elements towards a sustainable



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

innovation ecosystem that will operate under a holistic framework of organizational learning and promotion of educational innovations.

- Become an agent of community well-being. CLEVERFOOD exhibition (and the related materials) aims to support schools to develop projects that are proposing solutions to the needs of their local communities. To do so the CLEVERFOOD approach will explore the notion of well-being of students (including concepts of equity, gender inclusion and empowerment). By creating a model of collaboration with local stakeholders and by using activities that require the involvement of different actors, the participating schools will be linked with their local communities in a much deeper level. The adaptation of the activities will entail linking their subjects to issues of national interest in connection with the grand global challenges. Schools will thus aim to “act locally but think globally”, a motto developed already a few years now but still far from the reality of most schools in Europe today. In this way, these schools will enrich the science capital of the local communities and will promote responsible citizenship.
- Promote partnerships that foster expertise, networking, sharing and applying science and technology research findings and thus bringing real-life projects to the classroom. The project partners, both individually and in collaboration, have been developing, testing and promoting innovative educational applications and approaches for European schools (supported by relevant appliances and resources) for many years, which promote sharing and applying of frontier research findings in schools, supporting the developments of 21st century competences through creative problem solving, discovery, learning by doing, experiential learning, critical thinking and creativity, including projects and activities that simulate the real scientific work (e.g. organic farming and healthy food, food waste management). Each school will bring together representatives from industry and civil society associations who – in cooperation with school community – will scan the horizons, analyse the school and community needs and will cooperate to design common projects and to propose innovative solutions.
- Focus on Effective Parental Engagement. The innovation agenda builds on the notion of science capital of schools’ communities. Whilst science and technology are often seen as interesting to young adolescents, such interest is not reflected in students’ engagement with school science that fails to appeal to too many students. Girls, in most European countries channel away from science and only a minority of girls pursues careers in physical science and engineering. The reasons for this situation are complex but need to be addressed. For example, the role of students’ families in their selection of future career has been much stronger than what previously expected.
- Teach science for difference: Gender Issues. Instructional methods that foster students' understanding while allowing for different educational methods to be implemented in science classes might contribute to girls' participation and performance in advanced science classes while also supporting the learning of many boys. By implementing approaches that respect the fact that students are individuals with different needs and by applying a variety of methods, and approaches in the classroom the school may create more gender inclusive classrooms that would appeal to different types of learners and not the so called ‘implied learner’ that typical school lessons are designed for. This could be accomplished by for example sharing ideas, arguing, asking questions and analysing data in small groups of students who work in collaborative manner. This is an approach that clearly reduces the competitive nature of the whole classroom (teacher-centred) approach. The CLEVERFOOD educational activities and projects are based on pedagogical approaches that produce the outcome of proportional participation of all genders. More specifically the proposed standardization process will:
 - Adopt and integrate informal and formal educational experiences that intervene and reverse traditional patterns of low participation; encourage all students interest and girls in particular, enthusiastic participation, and election of continued study in math and science; increase confidence; and give girls positive images of math and science learning and careers.
 - Integrate awareness of gender bias in educational environments, and change organizational commitment, policy, and action to remedy under representation through student and faculty programs, for example, undergraduate departments in engineering, physical science, or computer science making a concentrated effort to increase recruitment and retention.



- Adopt and integrate new courses and curriculum that are gender-neutral or appeal particularly to girls and women. For example, think about including individual work, group work, and dyad interactions during the time of a lesson to involve a variety of different interaction forms and accommodate the needs of different students.

In this chapter we will identify the "design features" to be adopted, its theoretical basis and the research or evaluation basis for the "model," and address the benefits and issues bearing on integration in their educational setting.

2.5 Design Features of the CLEVERFOOD Educational Pathways

The activities that will be implemented in the participating schools are based on the essential features of creative learning including exploration, dynamics of discovery, student-led activity, engagement in scientifically oriented questions, priority to evidence in responding to questions, formulations of evidence-based explanations, connection of explanations to scientific knowledge, and communication and justification of explanations. These elements support creativity as a generic element in the processual and communicative aspects of the pedagogy and proposing innovative teaching strategies that will offer students high participation and enable them to generate highly imaginative possibilities.

At the same time, the CLEVERFOOD approach is based on the main principles of Responsible Research and Innovation process: learners' engagement, unlock of their full potential, sharing results and provide access to scientific archives, designing innovative activities for all.

Based on that, the participating schools will promote a series of educational activities in the form of real-life projects that will utilize innovative ideas and creativity and empower students to actively engage themselves in the learning process and improve their conceptual understanding in various scientific topics. It is therefore intended that the educational practices and strategies presented will allow science educators and specifically late primary and early secondary school teachers to identify creative activities for teaching science. Furthermore, the proposed pedagogy will aim to enable teachers to either create new creative activities or to properly assemble parts of different educational activities into interdisciplinary learning scenarios. In the framework of the CLEVERFOOD project the proposed activities will have the following four characteristics. They must be

- **Placed:** The activity is located, either physically or virtually, in a world that the student recognizes and is seeking to understand.
- **Purposeful:** The activity feels authentic; it absorbs the student in actions of practical and intellectual value and fosters a sense of agency.
- **Passion-led:** The activity enlists the outside passions of both students and teachers, enhancing engagement by encouraging students to choose areas of interest which matter to them.
- **Pervasive:** The activity enables the student to continue learning outside the classroom, drawing on family members, peers, local experts, and online references as sources of research and critique.

These four criteria can provide a useful checklist for teachers formulating their learning designs but also suggest what a science classroom and a school as an organization needs to offer to become more engaging in itself. These activities will be adapted by the school community that will involve representatives from educational providers, industries, civil society associations and even students themselves. The activities used in the project will promote collaborations and the opening of the classrooms to the society. The participating schools will include both primary and secondary education level and activities will be selected and adapted accordingly to fit the different levels.



2.6 Supporting Schools to become Sustainable Innovation Ecosystems

In our view the open school environments should provide more challenging, authentic and higher-order learning experiences, more opportunities for students to participate in scientific practices and tasks, using the discourse of science and working with scientific representations and tools. It should enrich and transform the students' concepts and initial ideas, which could work either as resources or barriers to emerging ideas. The open schools' environments should offer opportunities for teaching tailored to the students' particular needs while it should provide continuous measures of competence, integral to the learning process that can help teachers work more effectively with individuals and leave a record of competence that is compelling to students.

The involvement of the schools to the CLEVERFOOD project does not impose the implementation of a specific strategy towards openness. Through the intensive collaboration between the school community and the CLEVERFOOD team we are aiming to examine every collaboration as a separate case. In all cases however the project's team goal is to provide valuable guidance and to develop a sustainable support mechanism to assist both the school leadership as well as the teachers during the transformation process. In this report we are going to present a strategic implementation model and related milestones that could as a pathway towards the implementation of innovation in the school setting.

It must be noted though, that in each school case, in each participating country, multiple factors must be examined before a design, and implementation model will be placed in action. Factors taken into account in each case are: Local legislation and educational policies currently in place, Local educational culture, Current status of the school(s) in regards to existing curriculum/existing educational resources/ selected pedagogical approaches, Current status of the school(s) in regards to administration/teacher readiness towards embracing educational innovation and adopting an open schooling culture, Current status of the school(s) in regards to existing technological infrastructure, Current status of collaborators (government officials/school administrators/teachers/students), Scale of collaboration in regards to number of schools/teachers/students/other participants, Duration of collaboration and Total budget allocated.

In Europe there are many different school systems. An important and very crucial parameter for the introduction of innovation in the school setting is the level of autonomy at school level and the different levels of authority within the schools. The major challenge for CLEVERFOOD project is to find ways to propose activities and approaches that could be used from school heads in countries with a relatively low level of autonomy (e.g., Portugal, Italy) while at the same time attention should be given to education systems that can be categorized as autonomous (e.g. Finland, Sweden). In these countries, school heads tend to have a more managerial role that requires the school head to focus on motivational aspects.

The CLEVERFOOD approach can be perceived as an organisational change methodology, enabling the change agents to introduce the innovative theme of sustainable food systems in school practice. Well known organizational change methodologies prescribe a recommended pathway of stages or phases, consisting of particular activities to work through in order to achieve lasting change. In comparison with the most popular organisational change methodologies, the CLEVERFOOD approach includes the following steps to be regarded as suitable for education systems with a high level of autonomy at the school level:

- **Inspiration and Establishment of the need for change:** In some western European countries, teachers and school heads jointly decide on their pedagogic choices. In a few countries, the teachers have the final say in this matter. For both the innovative schools and the more traditional schools this proposed step is a vital part of an innovation implementation plan. In innovative schools there is a need to inspire teachers because the CLEVERFOOD initiative may be one of several proposed innovations that a school implements. Therefore, the teachers need to be convinced that the CLEVERFOOD project is more relevant than other options. In traditional schools the emphasis could be put on the urgency to change. These schools (the vast majority of schools in Europe) have less experience with innovative projects. The school heads and teachers at these schools should be made aware of the need to change. This step, the



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

inspiration of teachers and staff should be considered as a continuous process during all phases of the implementation and in most instances one of the main tasks of the school head.

- **Establishing a change team:** In most schools, innovations start small. A few innovative teachers, together with the school head lead the way and enthuse their colleagues during the implementation. School heads will initially engage teachers with low levels of resistance to change. During the project phases, teachers often look for other change agents to further implement the project in other subjects as well. The school head's role is to find the first few change agents and facilitate their work. This support could include an appropriate time compensation scheme.
- **Empowering the change team:** The change agents should be supported by the management of the schools during the implementation phases. Preferably, the change agents will be regarded as role models in their schools. Secondly, the change agents need to be supported by the continuous inspirational efforts of the school heads.
- **Organisational change:** Implementing change requires a teacher to experiment with innovative (from the teachers' perspective) pedagogic approaches. From an organisational perspective, the school head will need to implement an environment that supports experimentation by celebrating success and regarding failures as unique chances to learn. In true learning organisations, teachers are supported to take necessary risks (all changes come with risk taking and perceived uncertainty) and feel appreciate when they share the successes and failures.

2.7 Viable Change: Sustainability as a route to the future

After many years of working on European-wide reforms (including the Opening-Up Education Initiative by the EC, in 2013), the CLEVERFOOD consortium noticed the following phenomenon: Individual school heads became almost as concerned about the success of other schools in their areas as they were with the success of their own school. This is a direct result of being engaged in a larger purpose and getting to know other schools through walk-throughs and other lateral capacity-building strategies. These strategies might involve small clusters of schools working together to improve literacy or principals and teachers conducting walk-throughs of a school or schools to provide critical feedback to the staff. Their worldviews and commitments increased to encompass the larger system, but at the same time, they helped change the very system within which they work. They literally changed their context. The key to sustainability is to change context: "Sustainability does not simply mean whether something will last. It addresses how particular initiatives can be developed without compromising the development of others in the surrounding environment now and in the future". Sustainability is about changing and developing the social environment. The CLEVERFOOD approach is not about the proliferation and the development of single schools; it is about creating new environments across the system through tri-level development, at school level, at the community level and at national level.

2.8 Practices for implementation

In an open schooling environment, it is important for school heads and teachers to recognise that there are key conditions that support deeper learning outcomes, and that these conditions are sequential and rely on and build upon one another. The cornerstone condition is a school-wide culture that focuses on learning and promotes the belief that everyone is collectively responsible for student outcomes. There are six practices common across the schools committed to open schooling. School heads and teachers must⁹:

- Empower learners
- Contextualise knowledge

⁹ Martinez, M. et al. 2014. How Deeper Learning Can Create a New Vision for Teaching. National Commission on Teaching and America's Future



- Connect learning to real world experiences
- Extend learning beyond the school
- Inspire learners by customising learning experiences
- Purposefully incorporate technology to enhance learning

For teaching to shift to facilitate powerful learning experiences - where students are empowered and inspired and learning is contextualized, connected to real life, wired, and extended beyond school - the role of the teachers must change to that of learning strategist. For a teacher to be a coach of learning, he or she must fluidly shift among a range of roles, including learning designer; facilitator; networker; and an advisor who coaches, counsels, mentors, and tutors depending on what is most needed to promote student learning.

Empowering students as learners

Teachers who focus on deeper learning see their first responsibility to empowering students. For this reason, they use pedagogical approaches that help learners become self-directed and responsible students rather than passive rule followers. The centrepiece of instruction is helping students develop an understanding of learning as a complex and ongoing process that entails seeking feedback, revising work and regularly reflecting on what one has produced, as well as on the choices and decisions made throughout the learning process. “Revision toward mastery” is therefore a main feature of the culture and the language used by schools committed to deeper learning¹⁰. Teachers provide feedback, as well as opportunities for students to receive feedback from peers, reinforcing the idea that learning does not end with their first effort. Improving their work through rounds of feedback, revision and reflection encourages students to better understand the amount of effort required to produce high quality work.

Contextualise knowledge so it is coherent

Teachers who work to achieve deeper learning student outcomes also contextualize knowledge, so it is coherent as a way to help learners acquire content knowledge. Teachers use guiding questions, common themes, and big ideas to provide a context for every assignment, classroom activity, and project. Teachers are involving students in project that are relevant to them and to the local communities. Teachers also can involve learners’ projects related to global challenges or major discoveries that changed our understanding about the world. Teachers often work together across multiple subjects to design integrated learning experiences to connect their otherwise separate subject-specific content.

Connect learning to real issues and settings

Teachers who focus on developing deeper learning competencies connect learning to real issues and settings to make it more meaningful for learners. Teachers ensure that there are frequent opportunities for learners to experience workplace conditions and expectations and address real world challenges and problem solving by interacting with professionals and experts in relevant fields, taking on a professional role when doing a project, or by connecting historical events to current issues.

Extend learning beyond the school

In addition to connecting to the “real” world, deeper learning-focused teachers find ways to extend learning beyond the school and construct powerful student learning experiences in a range of settings. As a result of long-term formal and informal relationships with research centers, museums, science centers and outreach groups, the classroom walls drop away and the entire community becomes an annex of the school in which learners have access to rich content, outside experts, additional resources, an authentic place and context for learning, and work-based experiences.

¹⁰ Lenz, Bob., Wells, Justin, Kingstone, Sally. 2015. Transforming Schools Using Project Based Learning, Performance Assessment and Common Core Standards. San Francisco, CA: Jossey-Bass.



Teachers who focus on deeper learning inspire learners by customizing learning experiences. Teachers are intentional in establishing strong relationships with learners for the purpose of finding what will ignite their interest to pursue their own learning. Teachers use independent projects to both customize learning and provide inspiration for all their students.

Use technology in service of learning

Teachers who focus on developing deeper learning competencies use technology in service of learning. Teachers purposefully incorporate technology to enhance, rather than automate learning; regularly employ technology tools to support student learning and to engage learners in their own education; and shift their role away from being the sole gatekeeper to knowledge.

LEARNING WITH AND FROM THE EXTERNAL ENVIRONMENT AND LARGER SYSTEM

- The school scans its external environment to respond quickly to challenges and opportunities
- The school is an open system, welcoming approaches from potential external collaborators
- Partnerships are based on equality of relationships and opportunities for mutual learning
- The school collaborates with parents/guardians and the community as partners in the education process and the organisation of the school
- Staff collaborate, learn and exchange knowledge with peers in other schools through networks and/or school-to-school collaborations
- The school partners with higher education institutions, businesses, and/or public or non-governmental organisations in efforts to deepen and extend learning
- ICT is widely used to facilitate communication, knowledge exchange and collaboration with the external environment

Figure 4: A graphical representation Modelling and Growing Learning Leadership. Source: OECD/UNICEF (2016): What makes a school a learning organisation? A guide for policymakers, school leaders and teachers, p.8.12

2.9 Key Conditions Supporting the Development of an Open Schooling Culture

For teaching to shift to facilitate powerful learning experiences like the ones described above - where students are empowered and inspired and learning is contextualized, connected to real life, wired, and extended beyond school - the role of the teacher has to change to that of learning strategist. For a teacher to be a coach of learning, he or she must fluidly shift among a range of roles, including learning designer; facilitator; networker; and an advisor who coaches, counsels, mentors, and tutors depending on what is most needed to promote student learning. Therefore, in the framework of CLEVERFOOD implementation, it is important for the national coordinators, the school heads and the teachers to recognize that there are key conditions that support the development of an open schooling culture and strategies, and that these conditions are sequential and rely on and build upon one another. The cornerstone condition is a school-wide culture that focuses on learning and promotes the belief that everyone is collectively responsible for student outcomes.

¹² OECD (2016) What makes a school a learning organisation? Directorate for Education and Skills.
(<https://www.oecd.org/edu/school/school-learning-organisation.pdf>)



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

First, a learning culture must be established that values the need to learn, as well as students' need to learn how to learn, to become self-directed, and to develop an academic mindset that potentially will help them to consider scientific careers in the near future.

Create shared responsibility for student learning

The corresponding condition in support of teaching in an open school is a culture in which everyone is collectively responsible for student learning. This culture has to be purposefully established for students and teachers alike and is most developed by building relationships that ensure students are known well by both adults and peers, and that there are regular and systemic opportunities for frequent conversations among teachers, students, peers, and other adults.

Establish a culture of trust and professionalism

Furthermore, it is important to establish a culture of trust and professionalism as a condition that supports learning in an open school environment. The shift in culture is critical to making sure teachers feel supported and empowered to take on new roles, and to ensure that daily work and interactions are aligned to the open schooling plan and vision. Trust empowers individuals to be their best selves and creates a sense of shared accountability between and among the staff. Shared accountability can encourage greater feelings of trust among teachers and between teachers and school heads. School heads who trust teachers and treat them as professionals may also invite teachers to share in the leadership of the school with them, meaning teachers have substantial influence on school-based decisions, especially around issues of teaching and learning.

Preserve time for teachers to collaborate

These shifts in culture and roles require settings that foster deeper the open schooling culture and establish and respect time for teachers to collaborate. During this collaboration time, teachers can draw upon each other's expertise to design or revise meaningful learning experiences for students; address problems impacting the classroom and the school at large; and strategize how to improve their individual practice and student learning. Structured opportunities to work together can take the form of teacher-directed and school embedded professional development by peers or third parties on how to use specific pedagogical approaches. Teachers can also use their structured time together to identify and share the technology tools, apps, or resources they have found to assess students for mastery of content and critical thinking as well as other skills and personalize instruction to meet the unique learning needs of each student.

2.10 Definition of Implementation Parameters

Resource-Based Learning and Use of Unique Open Educational Resources

Subjects like science provide an opportunity to exploit Resource-Based Learning (RBL) alternatives, expanding both the materials and the methods used in teaching and learning. Resource-based learning "...involves the reuse of available assets to support varied learning needs"¹³. Several factors make RBL viable: 1) increased access to resources (print, electronic, people) in a variety of contexts not previously available; 2) resources are increasingly flexible in their manipulation and use; and 3) economic realities dictate that resources become more readily available, useable, and shareable across a variety of contexts and purposes.

Components of resource-based learning

RBL features four basic components: enabling contexts, resources, tools, and scaffolds. Taken together these components enable educators to create and implement learning environments of considerable diversity and flexibility. Table 3 provides an overview of key characteristics

¹³ https://en.wikipedia.org/wiki/Resource-based_learning



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

Table 3: Components and Characteristics of Resource-Based Learning (RBL)

RBL Components	Key Characteristics
Enabling contexts	Imposed: Teacher or external authority determines goal. Induced: Learner or learner and teacher determine the goal.
Resources	People, things or ideas that support the learning process.
Tools	Objects used to help facilitate the learning process. Range from processing to organization to communication tools.
Scaffolds	Support that is faded over time. Includes conceptual, metacognitive, procedural and strategic scaffolds

Enabling contexts

Enabling contexts supply the situation or problem that orients learners to recognise or generate problems and frame their learning needs. By creating and enabling contexts, meaningful learning can occur with and through the resources provided or obtained.

Resources

Resources are “raw materials” that support learning, such as electronic databases, textbooks, video, images, original source documents, and humans. Resources maybe provided by a more knowledgeable other (e.g. teacher) to assist others in extending or broadening knowledge or understanding. Resources may also be gathered by the learner as questions and/or needs arise. Given varying contexts of use, the utility of a resource may change dramatically from situation to situation. The web for example enables access to millions of resource documents, but their integrity and usefulness is judged by the individual and in accordance with the context of use.

Tools

Tools enable learners to engage with and manipulate both resources and ideas. Tool uses vary with the enabling contexts and user intentions; the same tool can support different activities and functions. Eight types of tools are used in RBL: processing, seeking, collection, organisation, integration, generation, manipulation, and communication.

Processing tools help students to manage the cognitive demands associated with RBL. Processing tools, such as self-directed learning systems, for example, enable learners to work with ideas, extending their cognitive abilities and reducing the need to “remember” or engage in unnecessary mental manipulation.

Seeking tools (e.g. keyword searches, topical indexes, search engines) help to locate and access resources. Seeking tools can also be specific to a particular context. For example, “Sustainable Table” provides an educational portal that offer access to numerous resources, activities and games and promotes the positive shift toward local, small-scale sustainable farming. Sustainable Table was created to educate consumers on food-related issues, and to help build community through food (<https://www.sustainabletable.org.au/about>).

Collection tools, ranging from paper-based worksheets to high-end smart phones, aid in amassing resources and data for closer study. Learners might use collection tools as they explore a learning space or after completing a tour. For example, the MEATRIX site (<http://www.thematrix.com/interactive/>), which includes an animated, 360-degree interactive industrial dairy farm scene, provide an entertaining way to give students an overview of the problems associated with factory farms.

Organisation tools are used to represent and define relationships among ideas, concepts, or “nodes”. Like collection tools, organisation tools range from electronic to non-electronic devices. Concept mapping tools



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

(e.g. www.inspiration.com) are powerful devices that enable users to demonstrate relationships and links between and amongst ideas.

Integration tools help learners to relate in a new way with existing knowledge, which helps to both organise and integrate ideas. Integration tools might range from a word processing program to a web site.

Generating tools as simple as a web site or as sophisticated as a modelling tool (e.g. <https://sustainablenutritioninitiative.com/models-tools/>) help learners to create “objects” of understanding.

Manipulation tools, which also range in their complexity, are used to explore beliefs and theories-in-action.

Finally, **communication tools** (both synchronous and asynchronous) support efforts to initiate or sustain exchanges among learners, teachers, and experts.

The central role of the exhibit “The Journey of the Tomato” is presented along with numerous resources that will form the proposed educational pathway. Chapter 3 presents two indicative educational pathways with reference to the specific exhibit.

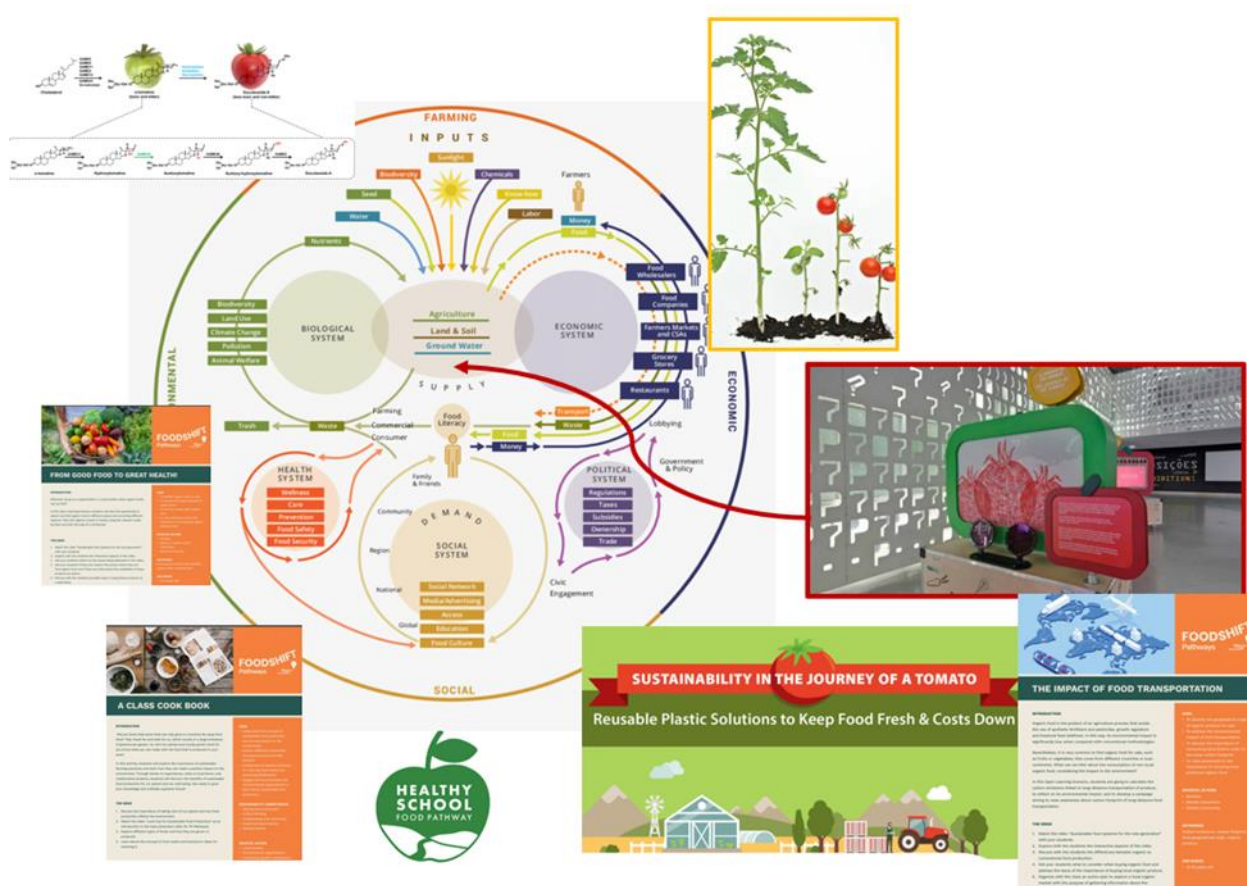


Figure 5: The CLEVERFOOD Exhibition will be enriched with numerous digital resources forming Educational Pathways that will engage students in related and interconnected activities. Through the proposed contextualised approach, the hypothesis, the instruments used, the observations will be presented in a form of a storyline that will help the visitor to realise the key challenges for the future food systems.



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

3. Indicative Educational Pathways

In this chapter we are presenting two indicative Educational Pathways that are related to the “Journey of a Tomato” exhibit. The exhibit offers a unique exploration of the extensive distances food travels before it reaches our tables. The first pathway is based on numerous scientific data and archives related with the ecological footprint of the tomatoes. A full analysis is presented along with the data sources (<https://ourworldindata.org/>). The aim of this pathway is to introduce students to an in-depth investigation and study of all parameters that have an impact on the ecological footprint of a commonly used vegetable. The second pathway describes a long-term project that engages students in real scientific processes that teach and reinforce inquiry skills, while they explore concepts related to plants, space, careers, nutrition and agriculture.

3.1 The Environmental Impact of Tomatoes: From Farm to Table

Tomatoes are one of the most consumed vegetables in EU and the major dietary source of the antioxidant lycopene, which has been linked to a reduced risk of heart disease and cancer. They also are a great source of vitamin C, potassium, folate, and vitamin K. Yet, much less is shared about the effect tomatoes have on the planet. So, we had to ask: What is the environmental impact of tomatoes? In this scenario, we will examine the environmental impact of tomatoes from several different angles. We will go through the life cycle of tomatoes, detailing their impact on the environment from growth to distribution to your plate to waste management. We will then compare the environmental impact of tomatoes to that of other vegetables. And, finally, we'll share some tips with you on how you can reduce your own environmental impact and offset your own carbon emissions – both for your personal life and tomatoes-related.

How do we assess the Environmental Impact of Tomatoes?

The Environmental Impact Assessment (EIA) is one of the ways we measure the potential environmental effects of our actions, like the consumption of tomatoes. **It is a holistic assessment based on the environmental changes associated with our consumption.** Those are changes in our environment that can have adverse effects on the air, land, water, fish, and wildlife or the inhabitants of the ecosystem.

Basically, **all goods and services you buy – including tomatoes – leave an impact on our environment.**

When it comes to food in general, and tomatoes in specific, the following are key factors:

- **Land requirements:** Large parts of the world that were once covered by forests and wildlands are now used for agriculture. 10 million hectares of forest are destroyed annually and 50% of the world's habitable land is now used for agriculture. This loss of natural habitat has been the main driver for reducing the world's biodiversity.
- **Water footprint:** 70% of global freshwater is now used for agricultural purposes. By assessing the water footprint of a particular food, we can determine how our limited freshwater resources are being consumed and polluted.
- **Pesticide and fertilizer usage:** Pesticides and fertilizers provide a range of agricultural benefits. However, numerous studies link pesticides and fertilizers to serious effects on human health, along with disruptions to vital ecosystems and the spread of aquatic dead zones.
- **Carbon footprint:** The carbon footprint is one of the ways we measure the effects of our human-induced global climate change. Today, food production accounts for over a quarter (26%) of global greenhouse gas emissions.



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

- **Waste generation:** Food and its packaging account for almost 45% of the materials landfilled in the US alone. And packaging sent to landfills, especially when made from plastics, does not degrade quickly or, in some cases, at all.

To understand the overall environmental impact of tomatoes, we must assess each of their key factors. This Environmental Impact Assessment (EIA²⁶) is a tool originally developed to identify the environmental impacts of a project prior to decision-making and helps us to evaluate the environmental impacts of tomatoes, from farm to table. All crops have an impact on the environment, as a great many resources, like land and water, are needed to produce food on a mass scale. **Unfortunately, tomatoes have the second highest carbon footprint of any vegetable, due to their land usage and the resources used in the growing period. This means that relative to other vegetables, tomatoes are a rather high-impact choice.** So, let's have a look at the environmental impact of each key factor of tomatoes:

Key Assessment Factors	Environmental Impact
Land requirements for tomatoes	Tomatoes require a lot of land to grow, meaning that their environmental impact is quite high. As one of the most land-intensive plant-based foods, often imported from other countries, this crop contributes to soil erosion, biodiversity loss and carbon emissions from transportation.
Water footprint of tomatoes	Overall, tomatoes have a relatively small global average water footprint of 180 litres per kilo of produce. They require irrigation, in a lot of cases, which has a negative impact on freshwater and ocean pollution. However, in comparison to other crops, they are not overly water intensive.
Agrochemical usage for tomatoes	Tomatoes tend to require agrochemicals, such as pesticides, and nitrogen, phosphorus, and potassium fertilizers. This vegetable can be vulnerable to disease and crop failure, so compared to other crops, the agrochemical use can be significant. Thus, the environmental impact is relatively high.
Carbon footprint of tomatoes	Tomatoes have a relatively high carbon footprint of 1.6 kg CO ₂ per kilo of produce. The main factor for these emissions is agriculture, which accounts for 94.53% of the overall carbon footprint of tomatoes, because of the large amount of land needed to grow this crop.
Waste generation of tomatoes	A massive 31% of fresh tomatoes are wasted annually, which is the equivalent of each person in the country throwing out 21 tomatoes a year. For every pound of food waste, 1.13 kg of CO ₂ is emitted. More research needs to be undertaken on the overall impact of the End-of-Life stage of tomatoes but buying loose produce and composting tomato waste are steps that we, as individuals, can take to reduce the carbon footprint.

These are the overall summaries of the environmental impact of tomatoes, but there is a lot more to the story. In the next few sections, we will dive deeper into each stage to illustrate to you all the important aspects of tomatoes' environmental impact.

²⁶ <https://www.unep.org/resources/report/environmental-impact-assessment-and-strategic-environmental-assessment-towards>

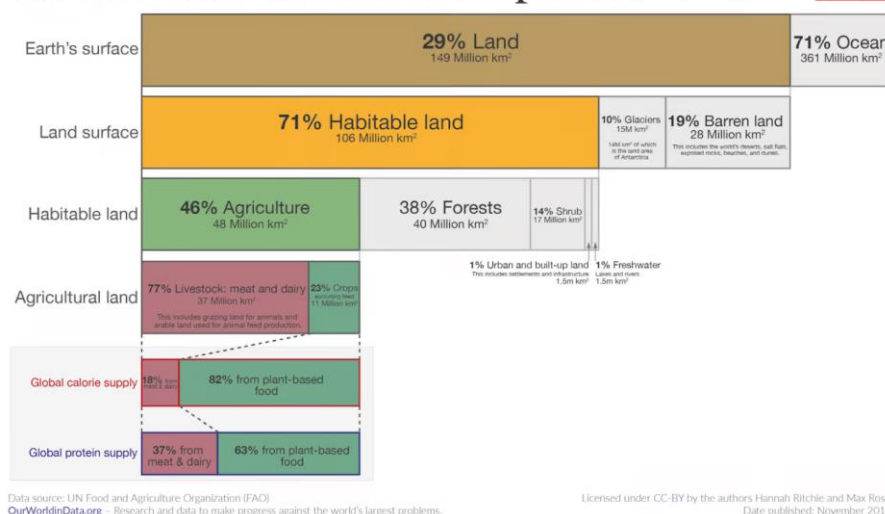


Tomatoes require a lot of land to grow, meaning that their environmental impact is quite high. As one of the most land-intensive plant-based foods, often imported from other countries, this crop contributes to soil erosion, biodiversity loss and carbon emissions from transportation.

Growing tomatoes has a lot of variables that contribute to their environmental impact. The amount of land they use, the way in which they grow, and the amount of time they take to grow will all contribute to their environmental impact.

Global land use for food production

Our World in Data



How do the land requirements of tomatoes impact their environmental footprint?

- **What is the land usage of tomatoes:** Across the globe, 12.4 million acres (5 million hectares) are used to grow tomatoes. Per 1,000 kilocalories of tomatoes, 4.21 m² of land is used, making them one of the most land-intensive plant-based foods. This is a large reason why the carbon footprint of tomatoes is high, though advancements are being made in vertical farming, to yield more crops using far less land.
- **Where and how are tomatoes grown:** Tomatoes are part of the Solanaceae family, and are an incredibly labour-intensive plant to grow. There are two types of tomatoes; determinate, which grow on bushes, and indeterminate, which grow on vines. Labor shortages in different EU countries means that more tomatoes are imported as opposed to grown domestically. This international transport impacts the carbon footprint in a negative way.
- **How does the growing of tomatoes affect soil fertility and erosion:** Tomatoes are grown in sandy soils, so the potential for soil erosion is far higher when growing tomatoes than when growing other crops, such as cereals or oilseed. This negatively impacts the environmental footprint of tomatoes, as soil erosion reduces the fertility of soil and can lead to flooding and water pollution.
- **How does the tomato industry affect the loss of habitable land:** Overall, agriculture uses 44% of the planet's habitable land, with two-thirds of this being used for grazing livestock. This means, overall, 14.7% of habitable land is used to grow crops. Since tomatoes are a land-intensive crop, compared to other plant-based foods, the tomato industry can have a negative impact on the loss of habitable land.
- **How does the tomato industry affect wildlife and biodiversity:** The tomato industry, like any other farming industry, has a negative impact on wildlife. Small creatures like mice, rabbits, birds, and insects are often displaced or killed in the harvesting process. Moreover, the use of pesticides when growing tomatoes can contaminate habitats, leading to degradation and the population decline of amphibians, birds and pollinators.

In short, compared to other crops, the land requirements of tomatoes negatively affect the overall environmental impact. They require lots of land to grow, which can lead to soil erosion, as well as loss of habitable land and biodiversity.

What Is the Water Footprint of Tomatoes?



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

Overall, tomatoes have a relatively small global average water footprint of 180 litres per kilo of produce. They require irrigation, in a lot of cases, which has a negative impact on freshwater and ocean pollution. However, in comparison to other crops, they are not overly water intensive.

Water usage is one of the most important factors in the environmental impact of a fruit or vegetable. The amount of water used, as well as the way they affect the water sources around them, are all major contributing factors. Here, we will look at these different angles of tomatoes' water impact.

How does the water footprint of tomatoes impact their environmental footprint?

- **What is the overall water usage of tomatoes:** 4 to 300 liters of water are needed to grow 1kg of tomatoes. Since plants in hot climates transpire far more than those in colder climates, tomatoes grown in cooler temperatures use a lot less water. This is a relatively low amount of water in comparison to other fruits and vegetables, such as soybeans, which require almost 10 times the amount of water.
- **What is the green water footprint of tomatoes:** The green water footprint is the amount of water from precipitation stored in the soil and used by plants for growth. The global average green water footprint of tomatoes is 108 cubic meters per ton, one of the lowest out of the over 200 foods studied. This means their environmental impact is low.
- **What is the blue water footprint of tomatoes:** The blue water footprint is the amount of water sourced from surface (such as rivers or lakes) or groundwater resources. The global average blue water footprint of tomatoes is 63 cubic meters per ton, which is relatively low compared to most of the other 200 foods studied. This means they have a rather small impact on the environment.
- **What is the grey water footprint of tomatoes:** The grey water footprint is the amount of freshwater required to clean up water pollution to meet certain quality standards. Essentially, it's the amount of water needed to make polluted water clean enough to be safe and healthy for humans and the environment. The global average grey water footprint of tomatoes is 43 cubic meters per ton, one of the lowest out of the over 200 foods studied, meaning tomatoes have a low grey water footprint.
- **How does the tomato industry affect freshwater and ocean pollution:** In Spain, tomatoes have to be watered using irrigation systems to meet the crop water use or crop evapotranspiration (ETc) requirements of processing tomatoes. Intensive irrigation can impact freshwater and ocean pollution by increasing erosion and transporting pesticides and heavy metals into water supplies. As well as this, it can cause a buildup of the toxic metal, selenium, and decrease the amount of water that flows naturally in streams. Therefore, the irrigation of tomatoes has a negative impact on water pollution.

Table 2. Product Water Use (PWU) in litres of water for 1kg fresh tomatoes grown in various climates and growing systems. Source: Van Kooten et.al., 2008

Tomatoes - production method	Country	litres/kg
Open field, general	Various*	100-300
Open field with drip irrigation	Israel	60
Unheated plastic greenhouse ('parral')	Spain	40
Unheated glasshouses	Israel	30
Unheated plastic 'parral', regulated ventilation	Spain	27
Advanced controlled glasshouses with CO2	Netherlands	22
As above with closed hydroponic system	Netherlands	15
As above but closed greenhouse	Netherlands	4
Greenhouse with evaporative cooling	Mexico	Est. 100 **
* Countries: Israel, Spain, Turkey.		
** water for evaporative cooling (estimate only).		

In short, tomatoes have a relatively small water footprint compared to other crops. However, the intensive farming of any crop will negatively affect the environment.

What Is the Agrochemical Usage for Tomatoes?

Tomatoes tend to require agrochemicals, such as pesticides, and nitrogen, phosphorus, and potassium fertilizers. This vegetable can be vulnerable to disease and crop failure, so compared to other crops, the agrochemical use can be significant. Thus, the environmental impact is relatively high. Pesticides and fertilizers are agrochemicals that can have a significant impact on the environment. They both require resources to create as well as have effects on the life around them. Here, we will look at how tomatoes' pesticide and fertilizer rates affect their environmental impact.



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

How does the agrochemical usage of tomatoes impact their environmental footprint?

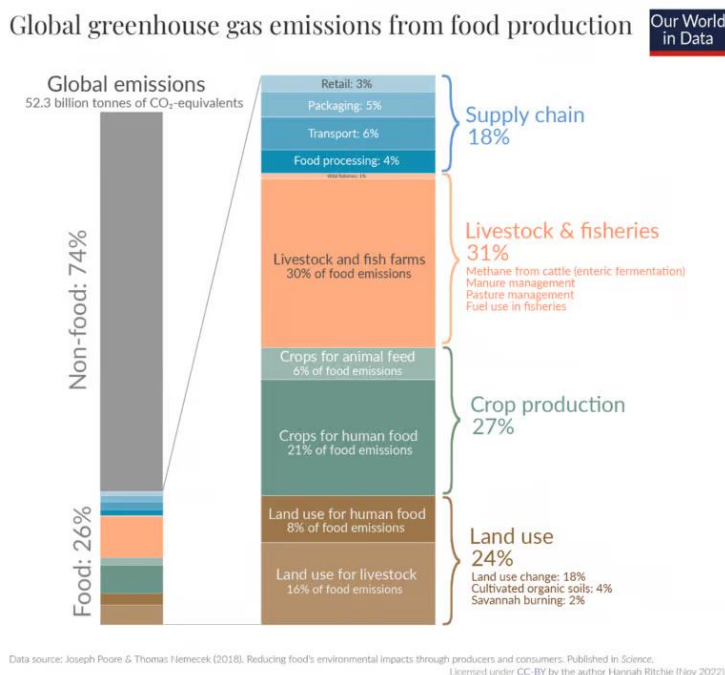
- **What is the pesticide usage of tomatoes:** Tomatoes are found to have the 12th highest pesticide usage out of any fruit and vegetable in the EU. An average tomato has 4 different pesticides used on it, and some have up to 15. Pesticides produce carbon emissions through their manufacturing, transportation, and application to crops, so tomatoes are a high-impact crop in this regard. A move towards vertical farming would require less pesticides. To lessen the environmental impact of tomatoes, opt for organic produce.
- **What is the fertilizer usage of tomatoes:** Compared to other vegetables, tomatoes often use more fertilizer, particularly nitrogen, phosphorus, and potassium. However, nitrogen fertilizer, which is particularly bad for the environment, is only used sparingly on tomatoes, as it can impact growth.
- **Are there any known issues connected to the agrochemical usage for tomatoes:** Most varieties of tomatoes that are sold commercially tend to be highly sensitive to disease and vulnerable to crop failure. Because of this, many agrochemicals are used to increase yield. This can lead to adverse environmental and health impacts because of the toxic chemical deposits, and water and air pollution.

In short, tomatoes are a relatively vulnerable crop, meaning that agrochemicals are often used, which negatively impact the environment.

What Is the Carbon Footprint of Tomatoes?

Tomatoes have a relatively high carbon footprint of 1.6 kg CO₂e per kilo of produce. The main factor for these emissions is agriculture, which accounts for 94.53% of the overall carbon footprint of tomatoes, because of the large amount of land needed to grow this crop.

Carbon footprint is one aspect of the overall environmental impact of a fruit or vegetable. It essentially measures how much carbon, or other greenhouse gasses the production of tomatoes emits into the atmosphere. Emissions from product manufacturing, irrigation, transportation fuel, and landfills all add up to create the overall carbon footprint of a fruit or vegetable. Let's see how the carbon footprint of tomatoes breaks down and contributes to their environmental impact.



How does the carbon footprint of tomatoes impact their environmental footprint?

- **What is the overall carbon footprint of tomatoes:** The overall carbon footprint of tomatoes is 1.6 kg CO₂e per kilo of produce, which is relatively high for vegetables. Out of the ten most popular vegetables, tomatoes have the second highest carbon footprint.
- **What are the main contributors to the carbon footprint of tomatoes:** The main factors that contribute to the carbon emissions of tomatoes are the amount of land needed to grow this vegetable, as well as high pesticide requirements.
- **Which life-cycle stage of tomatoes has the highest carbon footprint:** The growing stage of tomatoes is 1.4 kg CO₂e per kilo of produce. This makes up an enormous 94.53% of the overall carbon footprint of tomatoes. They require a lot of land, which means that they are not the most sustainable crop to grow.



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

In short, compared to other vegetables, tomatoes have a very high carbon footprint. This means that they have a large impact on the environment. Because tomatoes are the most consumed vegetable, the scale of tomato consumption is high, and thus, the carbon emissions released when growing tomatoes are even higher.

What Is the Waste Generation of Tomatoes?

A massive 31% of fresh tomatoes are wasted annually, which is the equivalent of each person in the country throwing out 21 tomatoes a year. For every pound of food waste, 1.13 kg of CO₂e is emitted. More research needs to be undertaken on the overall impact of the End-of-Life stage of tomatoes but buying loose produce and composting tomato waste are steps that we, as individuals, can take to reduce the carbon footprint.

When fruit and vegetable waste, either packaging or organic materials, is disposed of, it can have a major impact on the environment. Whether it's damaging wildlife, getting into oceans, emitting methane, or dissolving into microplastics that contaminate groundwater, all these materials have their part to play. In this section, we will look at how tomatoes' waste affects the environment.

How does the waste generation of tomatoes impact their environmental footprint?

- **What is the packaging of tomatoes:** There are many methods of packaging tomatoes, including cardboard cartons, plastic boxes, plastic wrap, wooden crates, or cardboard boxes. Processed tomatoes are also packaged in a variety of ways, from aluminium cans to plastic bottles and glass jars. The most eco-friendly choice is to buy loose tomatoes, which have been packed in biodegradable boxes.
- **How is the packaging of tomatoes disposed of:** Some retailers are moving closer towards fully recyclable cardboard cartons for tomatoes. Most plastic film, or plastic cartons are difficult, if not impossible, to recycle. Choosing loose produce will reduce the harm of plastic waste and the need for recycling resources. Interestingly, studies are being made into using tomato waste as bio-lacquers for food packaging, which aims to reduce packaging waste of other products.
- **How are tomatoes disposed of:** Unfortunately up to 86.7% of tomatoes are thrown away due to appearance, before even reaching stores. The resources used to grow these crops just to discard them are enormous, and negatively impact the carbon footprint of tomatoes. To reduce this waste, the demand for 'wonky fruit and veg' has been rising. Buying imperfect produce will lead to farmers throwing away fewer crops. Tomatoes are completely compostable, though food waste in landfill is a big problem for the environment.

In short, food and plastic waste contribute to our planet's carbon footprint. Steps can be taken to reduce your individual waste, through buying loose produce and not over-consuming or throwing out tomatoes.

How Can You Reduce Your Environmental Impact and Offset Your Personal Carbon Footprint?

There are a few things you can do to mitigate some of the negative environmental effects of consuming tomatoes, while still enjoying them. You can also consider offsetting your personal and tomato-related carbon emissions, which work to remove carbon emissions elsewhere that are then attributed to you. Here, we will walk you through how to accomplish both things.

How Can You Reduce Your Environmental Impact When Shopping for Tomatoes?

In this section, we give you a short list of ways you can reduce the negative environmental effects of tomatoes, based on those parts of the life cycle of tomatoes that would otherwise most negatively impact the environment:



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

- 1 **Opt for packaging free produce:** If you are unable to find loose tomatoes, choose cardboard-based packaging as opposed to plastic. Plastic waste is hard to recycle and creates an abundance of issues for the environment.
- 2 **Buy locally:** Driving up demand for local produce reduces food miles and lessens greenhouse gas emissions. Making sure to buy tomatoes grown in your country or near to your location, instead of imported from other countries, will have a positive impact.
- 3 **Get creative with leftovers:** Try not to over-consume in the first place, but if you find yourself with extra tomatoes, make sauces, salsas, purees, pickles, or other recipes that preserve them. This will help reduce your carbon footprint in terms of food waste. If you are stuck for ideas, here are some recipes that might inspire you.

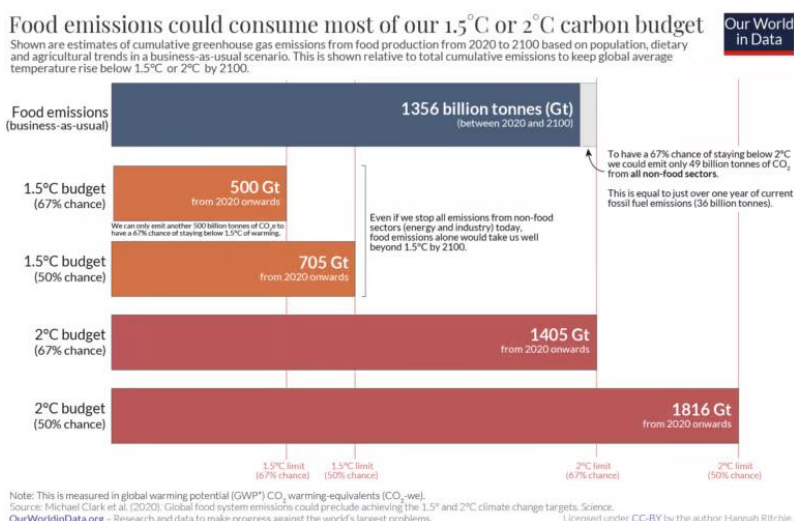
Following some of these methods can really help you to cut down on your environmental impact of eating tomatoes. None of these will completely eradicate these negative impacts, since there are always effects that may be outside of your control. But some reduction is always better than nothing!

How Can You Offset Your Personal Carbon Footprint?

The carbon footprint is a key part of your environmental impact. And it is one of the ways we measure the effects of our human-induced global climate change. Yes, even from eating tomatoes!

Basically, **it is the amount of carbon emitted by you as an individual or an organization providing you with goods and services – including tomatoes:**

- This includes GHG emissions from producing the products that we use and foods that we eat (e.g., power plants, factories or farms, and landfills)
- GHG emissions from fuel that we burn directly or indirectly (e.g., logistics and transportation, cooling or heating facilities),
- as well as the GHG emissions attributed to how we consume these products and foods.



Carbon offsets are reductions in carbon emissions that are used to compensate for carbon emissions occurring elsewhere – for example for the carbon emissions that are associated with tomatoes. They are measured in tons of CO₂ equivalents and are bought and sold through international brokers, online retailers, and trading platforms on what is known as the global carbon offset market. In terms of tomatoes – and indeed all food types – there will always be a carbon footprint, because of the resources it takes to get your food from farms to the place where you'll eventually eat them. And while there are ways to reduce your carbon footprint when shopping for tomatoes, carbon offsets would be a way to reduce your CO₂e emissions all the way down to net zero (or even to become climate positive).

However, when you purchase carbon offsets, it's important that they make a difference in offsetting (aka reducing) total carbon emissions. To achieve that, the following are key criteria:

- Carbon offset projects must be effective (different projects have different effectiveness rates)
- Carbon offset projects must be additional



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

- Carbon offset projects must be permanent
- The claims from carbon offset projects must be verifiable

To find the best carbon offsets for you personally, check out our full guide on the best carbon offsets for individuals, where you'll also learn more about how these carbon offset projects work, what their respective offsetting costs are, and what your best way would be to offset your own carbon emissions.

Final Thoughts

Since tomatoes use a lot of land and agrochemicals, they are a rather unsustainable crop to grow. Though there are lots of choices of fruits, vegetables, nuts, and pulses that produce less carbon emissions, it is unlikely that everyone will avoid the planet's favourite vegetable! By being aware of the environmental impact of tomatoes, you are in a better place to make reductions in food and packaging waste, and consciously consume. Try to reduce or offset your personal carbon footprint, so that you can enjoy a tomato dish in the most sustainable way possible.

3.2 You Can Grow Tomatoes from Seeds That Flew in Space!

If astronauts are going to settle on the Moon, or explore further reaches of our Solar System, they will need air, food and water. To prepare for long duration missions, scientists are researching how to create a closed life support system could be used in space, including how plants could be grown in such a system.

[Tomatosphere](#)²⁷, a Space Station Explorers partner program, is a curriculum-driven free program, K–12 students investigate how the space environment affects tomato seeds' germination and growth. The specific activity can be further expanded with the European Space Agency (ESA) educational activities "AstroFood"²⁸, where students investigate other possible future space foods, and the "AstroFarmer"²⁹, where students explore growing plants in space and factors that affect plant growth.

What does the program involve?

Each classroom is sent two packages of tomato seeds. One package contains seeds that have been sent into space, and the other package contains "control" seeds, which have been kept on Earth. Through the Tomatosphere project, students will learn how to conduct a scientific experiment and compare the germination rates of the two groups of seeds. Tomatosphere relies on a "blind test" in which educators and students will not know which of the two packages are the "space" seeds and which are control seeds until the germination process is complete and results have been submitted.

Watching these seeds germinate and grow will encourage classroom dialogue about the elements of life that support the requirements for space missions – food, water, oxygen and the need to consume carbon dioxide exhaled by astronauts. Travelling to and from Mars could take more than two years, therefore it is vital to know how to grow food while astronauts make the journey to the Red Planet, spend time on Mars and make

Learning Objectives:

- Observe and describe how seeds grow into mature plants
- Create scientific diagrams and use labels
- Execute systematic observations and measurements
- Interpret results and draw conclusions from the results
- Be able to perform comparative and fair tests

Equipment

- Printed student data logbook for each group
- Ruler
- 3 pots
- Soil or other growth medium
- Plant nutrients
- Basil, radish and tomato seeds

Time

30 minutes per week for 12 weeks

Resource available in:

English, Czech, Danish, Dutch, Finnish, French, German, Greek, Italian, Norwegian, Polish, Portuguese, Romanian, Spanish, Swedish

²⁷ <https://www.firsttheseedfoundation.org/program/tomatosphere/>

²⁸ https://www.esa.int/Education/Teachers_Corner/Astrofood_-_Learning_about_edible_plants_in_Space_Teach_with_space_PR41

²⁹ https://www.esa.int/Education/Teachers_Corner/Astrofarmer_-_Learning_about_conditions_for_plant_growth_Teach_with_space_PR42



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

the return journey back to Earth. The results from your Tomatosphere science experiments will help scientists understand some of the issues related to long-term space travel. It's an out-of-this-world opportunity for your students!

Why grow tomatoes in space?

Tomatoes are practical and valuable plants for space applications. They provide wholesome nourishment, as well as purified water through evaporation from their leaves.

Collecting and Recording Your Data

To ensure the consistency of observations made by numerous independent observers, the following criteria will be used to define the condition “successfully germinated”.

For purposes of this experiment, a seed can be considered to have successfully germinated when two (2) distinctly separate cotyledons (embryonic leaves) can be seen.

The primary objective of the experiment is to determine how many of the planted tomato seeds are successfully germinated. The image shows some peat pots with germinated tomato seeds. Note that the seedlings have only their embryonic leaves and no true leaves have yet appeared. Also note that each seed produces only one stem. The peat pot in the inset photo obviously contains two germinated seeds – evidence of not taking care when planting the seeds. It is important to be certain that each peat pot contains only one seed.



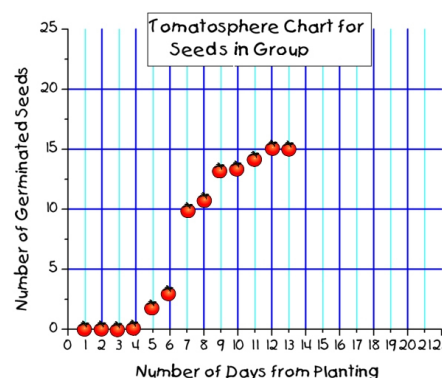
Check your planted seeds each day. The first signs of germination will be a small bud-like structure pushing its way up through the peat in the peat pellet. In some cases, the seed coat itself will be pushed upwards as it adheres to a cotyledon like a small helmet.

When two distinct cotyledons appear, germination can be considered to have been successful.

Keeping a class record

An excellent way to record your observations is to prepare a data chart, such as the one shown in the image. Make a separate chart for each group of tomato seeds.

Mark the number of elapsed days from the initial planting on the horizontal axis and the **total** number of seeds germinated on the vertical axis. Each day plot your class observations on the chart (students in this class have cut-out bright red “tomato markers” to plot their data, but a coloured “magic marker” works well). Display the graphs in your classroom where the results can be easily seen. The data collection for the experiment should be done on a daily basis for germination. Each day a different group of students can be



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

responsible for updating the classroom graph. Detailed and accurate record keeping is an important part of doing science.

- Each student should create a journal to record and track the progress of the experiment.
- The journal should contain two distinct sections for recording observations, one section dedicated to each experimental group of seeds.
- Students should prepare (in advance of starting the experiment) several pages in their journals in which to record each day's observations. By having the record pages prepared in advance a neat and complete set of observations can be recorded with a minimum risk of observations being forgotten or data being lost.

Note the conditions under which the observations were taken. For example, it would be useful to record the temperature by placing a thermometer in the region of each sample.

Journal for Group 			
yy/mm/dd	day	total	notes &
date	number	number	comments
		germinated	(changes in conditions etc.)
Feb 25 03/02/25	0	0	planted seeds
03/02/26	1	0	11 am 22°C
03/02/27	2	0	11:10 am 22°C
03/02/28	3	0	11 am 24°C
03/03/01	4	0	12 (lunch time) watered trays
03/03/02	5	0	weekend
03/03/03	6	0	weekend
03/03/04	7	2	11:15 20°C first seedlings
03/03/06	8	3	9:30 am 21°C watered trays
	9	4	
	10		
	11		
	12		

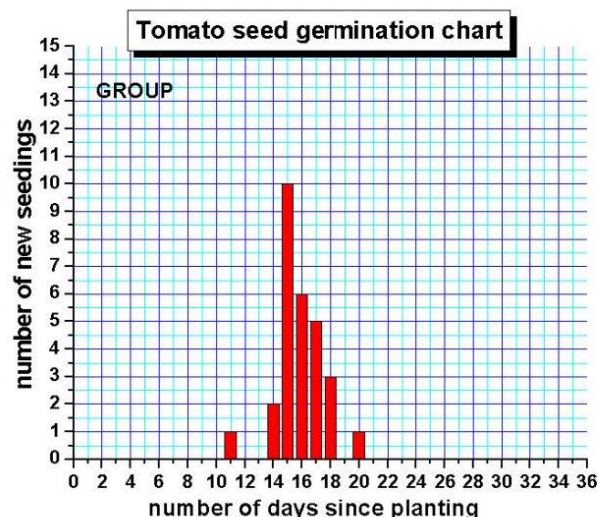
A typical journal page may look like the page shown in the image. Each day an entry is made into the data log, along with any comments or notes which might be useful when interpreting the data. For example, the temperature and the frequency of watering might prove important in understanding differences in germination rates when all the data are finally collected and compared. It is always better to record too much information than not

enough information.

In addition to keeping a table of the observations as the experimental results become available, it is helpful to keep a daily graph showing the progress of the experiment.

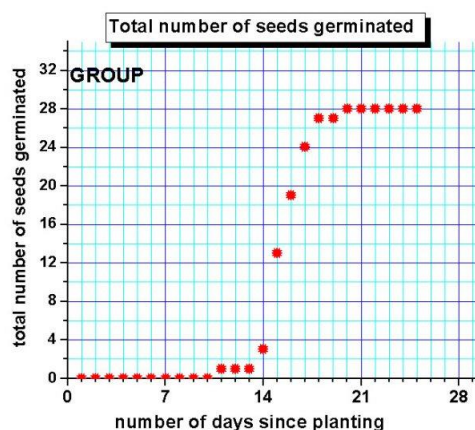
There are two kinds of graphs which are helpful.

The graph below plots the number of new seedlings that appear each day. A sample graph is provided as well as a copy master which can be used to generate class-sets of the blank graph; or you may wish to create your own. A separate graph should be created for each group of seeds.



A different way of recording the data is to plot the total number of seedlings which have germinated. When the graph shows that no further seeds are germinating, the germination part of the experiment is complete. A separate graph should be created for each group of seeds.

At the end of the Tomatosphere Experiment, you are asked to submit your results to the Project Manager. You will need the number of seeds planted and the number of seeds germinated for each group of seeds – the control group and those that have been to the ISS.



4. Conclusions

The educational pack of the FOOD 2030 Interactive Exhibition aims to present the conceptual framework of the exhibitions design and at the same time to extent its use beyond the duration of the visit and its location. It highlights the key messages of the CLEVERFOOD outreach programme and demonstrates how an effective content enrichment strategy can be developed by each individual visitor or whole school communities that are interested to implement project in the field of sustainable food systems. It is also providing detailed guidelines – along with examples of resources - for the design of inclusive experiences for all students. The document includes a detailed guidebook for the design of the Educational Pathways for the FOOD 2030 Interactive Exhibition. This document should be used along with the Exhibition Guide to facilitate the effective introduction of the theme/s to the targeted audience.

To realise the engagement of schools with their surrounding communities, school communities are encouraged to set-up collaborative projects to deal with global or local challenges, linking them to science education. Various practical approaches can be used to develop student-centred open schooling activities, including the influential Schools as Living Labs of Sustainable Food Systems methodology, whereby students collaborate with societal actors to co-create solutions to problems and challenges they identify in their everyday life and choose to address. An open school is a more engaging environment for learning, as learning in and together with the real world creates more meaning and more motivation for learners and teachers. The school environment fosters collaboration, mentoring, and provides opportunities for learners to understand and interrogate their place in the world. At the same time, it also makes a vital contribution to the community, as student projects meet real needs in the community outside school and draw upon local expertise and experience.

The design template of the Educational Pathways integrates the key features of the project's approach, it is based on the model of inquiry learning that has been adopted to support both virtual and physical field trips but also field trips across different museums and science centres, it makes use of the CLEVERFOOD network of scientific resources and archives project partners as well as for the educational community and overall consists a step by step guide for the project team and the educational community to design high-quality and engaging experiences for the students.



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

Annex A: the CLEVERFOOD Educational Pathways Templates

Learning science (or learning about science) is not the same experience and does not carry to same meaning for everyone. In addition to the varying perceptions of science learning, its nature, objectives and workings, the diversity of science learning instances is also attributable to the variety of personal and institutional circumstances in which it may occur. Thus, the characterisation of science learning objects alone cannot generate adequate momentum for effective and sustainable exploitation of the rich content of digital repositories, unless this content can be accessed by the intended users in purpose-appropriate, meaningful ways. This challenge is addressed by the CLEVERFOOD project through the employment of the concept of *Educational Pathways*.

The concept of Educational Pathway

The concept of *Educational Pathway* in CLEVERFOOD reflects the priority given by the project to responding to the needs of the diverse communities of potential visitors of the CLEVERFOOD exhibition. Thus, an *Educational Pathway* in the CLEVERFOOD project describes the organisation and coordination of various individual learning resources into a coherent plan so that they become a meaningful science learning activity for a specific user group (e.g., teachers, students, other museum visitors, etc.) in a specific context of use. Further, Educational Pathways directly serve the priority assigned by the project to the integration of resources scattered in various science museums/centres into the same learning experience rather than the mere selection of resources from a single museum or science centre. It should be kept in mind that an Educational Pathway may include only the use of digital content at a distance, without physically visiting the science museum or centre ('virtual visit'), or a combination of using digital content (at a distance or onsite) with a physical visit to the science museum or centre ('physical visit')³⁰. In the CLEVERFOOD approach, a Pathway is understood as a dynamic rather than static conceptual tool. In the envisaged optimal function of the CLEVERFOOD community, creators of Pathways may revisit, revise and continually develop their Pathways, or even use Pathways created by others as a basis for creating their own new versions, in a process reflecting social learning as a course of personal and communal gradual development in the learning community.

Educational Pathways user roles and use contexts: Defining the dimensions of digital-resource-based science learning

Central to the definition of the Educational Pathways is the definition of the user roles and use contexts anticipated. In other words, Pathways represent various combinations of users and contexts, with quite varying characteristics among them, sharing however an interest in using digital resources available in science museums and centres for science learning purposes – formally or informally.

The main CLEVERFOOD stakeholders are defined according to their roles as potential visitors of the exhibition as follows:

- *Teachers*: schoolteachers wishing to integrate the use of such resources in their teaching.

³⁰ Physical visits without an element of use of digital content use are beyond the scope of the CLEVERFOOD project.



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

- *Students*: school students who may use such resources either as part of their curricular learning, or in out-of-school learning (e.g. in free time or with family)
- *Science museum educators or science communication professionals*: Staff who prepare science learning or awareness raising experiences for the visitors/users of their institutions (science museums and centres). An additional subgroup here might also be other professionals too related to science communication, including journalists who may search for content relevant to the promotion of informal science learning.

Correspondingly, then, the contexts of use of the CLEVERFOOD may be organised into the following three categories:

- In the school (combined with one of the following two categories)
- In the science museum/centre (physical visit)
- On the web (virtual visit),

in the combinations presented in Table 4.

Table 4: Contexts of use of the CLEVERFOOD service

In the science museum/centre (physical visit)	On the web (virtual visit)
In connection with the school	In connection with the school
In <i>no</i> connection with the school	In <i>no</i> connection with the school

In these contexts, individuals and groups may get involved in the use of digital content either in ways pre-designed by someone (e.g., a teacher, or a museum educator), or employing their own creative ways of exploring and interacting with the digital content.

The Educational Pathways can then be seen as instances located in a system of possible combinations of use contexts, user roles, and varying levels of user independence (Table 5).

Table 5: Contexts of use, user roles, and user independence

	In connection with the school		In <i>no</i> connection with the school	
	In the science museum/centre (physical visit)	On the web (virtual visit)	In the science museum/centre (physical visit)	On the web (virtual visit)
Teachers	usually pre-structured (or exploratory)	usually pre-structured (or exploratory)	<i>As independent lifelong learners:</i> usually exploratory (or pre-structured)	<i>As independent lifelong learners:</i> usually exploratory (or pre-structured)



Students	usually pre-structured (or exploratory)	usually pre-structured (or exploratory)	<i>As independent lifelong learners:</i> usually exploratory (or pre-structured)	<i>As independent lifelong learners:</i> usually exploratory (or pre-structured)
(Other) lifelong learners	-	-	usually exploratory (or pre-structured)	usually exploratory (or pre-structured)
Science museum educators or science communication professionals	[structuring activities for others]	[structuring activities for others]	[structuring activities for others]	[structuring activities for others]

Such a system allows for possible dimensions of digital-resource-based science learning such as the following:

- Use of museum and science centre digital resources in school science education
 - Teacher-guided (top-down)
 - Student-driven (bottom-up)
- Use of museum and science centre digital resources in non-formal³¹ science learning
 - Curator-guided (top-down)
 - Visitor-driven (bottom-up)
- Use of museum and science centre digital resources in informal science learning
 - Curator-facilitated (top-down)
 - Visitor-driven (bottom-up).

In this context, a distinction between *pre-structured* and *open*³² pathways appear to be useful. An Educational Pathway is defined as *pre-structured* when it provides a rigid pre-defined 'route' through a set of science learning resources (mainly relevant to more formal learning contexts, e.g., the case of school science education, with specific curriculum references and teaching processes). On the other hand, an Educational Pathway is defined as *open* when it is more flexible and informal in its approach, allowing for considerable unbound user decisions, initiative and creativity in the ways the user will explore and exploit

³¹ The terms 'formal', 'non-formal' and 'informal' learning are used on the basis of existing EU definitions [e.g. A Memorandum on Lifelong Learning. Brussels, 30.10.2000. SEC(2000) 1832], with the following meanings: **Formal learning:** Learning typically provided by an education or training institution, structured (in terms of learning objectives, learning time or learning support) and leading to certification. Formal learning is intentional from the learner's perspective. **Non-formal learning:** Learning that is not provided by an education or training institution and typically does not lead to certification. It is, however, structured (in terms of learning objectives, learning time or learning support). Non-formal learning is intentional from the learner's perspective. **Informal learning:** Learning resulting from daily life activities related to work, family or leisure. It is not structured (in terms of learning objectives, learning time or learning support) and typically does not lead to certification. Informal learning may be intentional but in most cases it is non-intentional (or 'incidental'/ random). **NB:** The distinction between non-formal and informal learning is not usual in the field of science learning, and in particular providers such as science museums or centers may not feel comfortable with the distinction. In the present context, when no distinction is made between 'non-formal' and 'informal', the term 'informal' refers to the usual kinds of provision offered by science museums or centers.

³² The term '*semi-structured*' has also been proposed as an alternative to the term '*open*', as it is felt that '*open*' may imply an approach that is too un-specific to CLEVERFOOD (e.g. implying an experience like using Google on the web). The term '*open*' is retained at this stage but will be revised if experience from the next project phases points to such a need.



the science learning resources (as in the case of an adult independent visitor or a family, or even a teacher who has decided to involve her/his students in an open-ended exploration of the resources).

The Educational Pathway Patterns

Going one step closer to practical implementation, the *Educational Pathway Patterns* are the templates offered by the project for designing, expressing and representing Educational Pathways for a certain user group and type of visit. Two main types of Patterns seem to be capable of describing the various possible pathways: a *Pre-Structured* and an *Open Educational Pathway Pattern*, corresponding to the pre-structured and open educational pathways as described in the previous section. The proposed two Educational Pathway Patterns correspond to the various user groups as presented in Table 6.

Table 6: Educational Pathway Patterns and user groups

School community (teachers and students)	Pre-Structured Educational Pathway Pattern (<i>potentially also Open</i>)	Prepared by: - Teachers - Science museum educators etc.	Enriched with social metadata by: - Teachers - Students
'Lifelong learners'	Open Educational Pathway Pattern (<i>potentially also Pre-Structured</i>)	Prepared by: - Science museum educators etc. - Users / lifelong learners	Enriched with social metadata by: Learners

Structure of the Educational Pathway Patterns

In many cases, learning experiences should be ideally embedded in a context which provides the means for the preparation of the learner for the learning experience before it takes place, as well as for facilitating the retention and future exploitation of the outcomes of the learning experience for a longer time after it has taken place. This is a fundamental principle in formal education but can also be seen as a useful dimension (even if not that prescriptive) in informal learning environments. For this reason, the Educational Pathway Patterns propose the organization of the science learning experience in three steps:

- i) *Pre-visit*³³: activities preparing for the interaction with the digital learning science resources
- ii) *Visit*: activities involving interaction with the digital science learning resources in or outside the science museum/centre

³³ The term '*visit*' is used here metaphorically and does not necessarily imply a physical visit to a science museum or center. It is used in a technical sense in this document, to indicate processes before, during, and after interaction with the digital learning resource(s) in question. If felt necessary, in the next project steps it may be replaced by other more accurate or user-friendly terminology (e.g. '*pre-experience*', '*experience*', '*post-experience*'; or '*engage*', '*interact*', '*find out more*'; or even topic specifically, such as for example '*travelling with a light beam*', '*virtual visit to European museums*', '*more resources and ideas*'; etc).



iii) *Post-visit*: activities rounding up and concluding the learning experience, after the interaction with the digital science learning resources.

From these, the *Visit* phase is the core of the learning experience and indispensable in any Pattern. The *Pre-visit* and *Post-visit* phases are absolutely essential for the realization of effective connections between school science education with learning activities involving work with science museum/centre content; however these ‘auxiliary’ preparatory and follow-up phases may well or may not be relevant to and desirable for open visits by any lifelong learner (e.g. if the designer of an informal learning experience feels that the adoption of the three-phase scheme implies a linearity of sequential nature that does not correspond to the intended experience). Indeed, the degree of freedom or prescription in the design of a pathway has proven to be the most debated aspect of the CLEVERFOOD approach in the consortium, which brings together two considerably separate ‘worlds’: those of formal school education and informal learning in science museum and centres.

Thus, although each pattern should include sections corresponding to these three phases, in the case of an open pathway pattern the pre-visit and post-visit phases should be seen as possible but not obligatory. In addition to the three phases, there is an introductory section outlining the identity of the Educational Pathway and providing guidance for any preparations necessary before the launch of the learning activity. Each section consists of several fields, for each one of which a description and/or guideline is provided.

The Educational Pathway Patterns developed

From the various possible Educational Pathway Patterns that the project could develop, the most complex are those describing structured visits bridging formal and informal science learning through a school ‘visit’ (physical or virtual). Open ‘visits’ by independent informal learners, on the other hand, can be seen as simpler, little pre-defined experiences. Structured visits of non-school users that may be offered by some science museums or centres fall somewhere between the two ends of the ‘complexity and structure’ spectrum, their exact position depending on the degree of formality applied to the design of the visit by the science museum/centre.

Therefore, the present document proposes two structures as tools for use and experimentation at this stage of the project³⁴:

- The Educational Pathway Pattern for a Pre-Structured Visit by the School Community
- The Educational Pathway Pattern for an Open Visit by Lifelong Learners.

These two examples can guide the formulation of other Educational Pathways in the following project stages, based on the experience gained with these initial tools.

Educational Pathway Pattern for a Pre-Structured Visit by the School Community

From the various possibilities of interaction with the Virtual Pathway partners resources, structured visits of the school community correspond to the most complex, detailed and pre-defined Educational Pathways, reflecting the mapping sought between formal and informal learning practices. In the case of an *Educational*

³⁴ An alternative terminology that has been proposed as more user-friendly is ‘*pathways for educators/mediators*’ (addressing those who will use the CLEVERFOOD content to ‘educate’ or ‘inform’ or ‘involve’ others) and ‘*surf and learn*’ (addressing those independent users who use the CLEVERFOOD content for their own benefit/pleasure). The need for and usefulness of this and other alternative terminology will be examined in the next project phases.



Pathway for a Pre-Structured Visit by the School Community, the teacher or the museum educator selects school science subject matter (e.g., complex physical phenomena typically causing difficulties to students) to present it through student-centred and student-friendly multidisciplinary educational activities involving the use of digital science learning resources available through the projects' portal or website. The Learning Pathway should represent a learning experience connecting work in the classroom or school lab with virtual or physical visits to the CLEVERFOOD science museums/centres. The integration of resources scattered in various science museums/centres into meaningful learning experiences is a priority (rather than selecting resources from a single museum or science centre).

The underlying pedagogical approach for the structured visit

For the three steps of the learning process (Pre-visit, Visit, Post-Visit), the model of Inquiry-Based Learning is chosen as the guiding principle for structuring the activities foreseen by the structured Educational Pathways. Inquiry-Based Learning is currently the most influential approach to science learning, and particularly so in the field of school science education. According to it, learning should be based around learners' questions, as they work together to solve problems rather than receiving direct instructions from the teacher. The teacher should function as a facilitator helping students in the process of discovering knowledge themselves. In the science context in particular, learners use their background knowledge (of principles, concepts, theories) together with their science process skills to construct new explanations which allow them to understand the natural world; and learners are likely to begin to understand the natural world if they work directly with natural phenomena, using their senses to observe and using instruments to extend the power of their senses. This approach to science learning is part of a greater world of constructivist models of learning, which see learning as the result of ongoing changes in our mental frameworks as we attempt to make meaning out of our experiences.

In practical terms, it is proposed that teacher and learner activity be described in the Educational Pathways as an iterative process consisting of the following five phases:

Teaching Phase 1: Question Eliciting Activities

- **Provoke curiosity:** The teacher tries to attract the students' attention by presenting/showing to them appropriate material.
- **Define questions from current knowledge:** Students are engaged by scientifically oriented questions imposed by the teacher.

Teaching Phase 2: Active Investigation

- **Propose preliminary explanations or hypotheses:** Students propose some possible explanations to the questions that emerged from the previous activity. The teacher identifies possible misconceptions.
- **Plan and conduct simple investigation:** Students give priority to evidence, which allows them to develop explanations that address scientifically oriented questions. The teacher facilitates the process.

Teaching Phase 3: Creation

- **Gather evidence from observation:** Teacher divides students in groups. Each group of students formulates and evaluates explanations from evidence to address scientifically oriented questions.

Teaching Phase 4: Discussion



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

- Explanation based on evidence: The teacher gives the correct explanation for the specific research topic.
- Consider other explanations: Each group of students evaluates its explanations in light of alternative explanations, particularly those reflecting scientific understanding.

Teaching Phase 5: Reflection

- Communicate explanation: Each group of students produces a report with its findings, presents and justifies its proposed explanations to other groups and the teacher.

The above model is proposed as a guide of appropriate teaching practice built around the observation of objects or phenomena in the natural world – in this case physically or virtually, directly or indirectly, in the science museum/centre. Apparently, the Educational Pathway Pattern is flexible and open to other educational approaches, too, if considered more appropriate in certain circumstances. However, in any case it is advisable to retain the organization of the activities in a three-step scheme (before, during, after the ‘visit’).

The Educational Pathway Pattern for a Pre-Structured Visit by the School Community

A) Introductory section and preparatory phase

The following basic information about the intended learning experience is to be defined at the outset. This information should allow the teacher to assess the relevance of the resource to his/her teaching needs and particular circumstances and provide him with guidance for the preparation of the learning experience. Note that most of this information can be directly linked to scientific open educational resources or interactive exhibits that are offered from the CLEVERFOOD partners. The formalisation proposed there for certain elements is to be applied accordingly in this introductory section too.

Title:

Give a title that helps easily recognize the content focus and purpose of the Educational Pathway.

Short description:

A description of no more than 30 words outlining the scope of the Educational pathway, descriptive enough to help the user in the first instance to estimate its possible relevance to her/his interests.

Keywords:

A limited number of words/short phrases reflecting the topic and scope.

Target audience:

The intended end user: teacher with students, teacher, students, other...

Age range:

Up to 6, 6-9, 9-12, 12-15, 15-18...

Context:

The places that the Educational Pathway involves school, science museum/centre, independently on the web.

Time required:

The approximate time typically needed to realize the Educational pathway. This could be distinguished into the amount of time required for school-based work and science museum/centre-based work.



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

Technical requirements:

Description of any special technologies, infrastructure and/or technical expertise required for the realization of the Educational Pathway.

Author's background:

What was the main function of the person who prepared the Educational Pathway: schoolteacher; museum educator; parent; other.

Connection with the curriculum:

Reference to the items of the science learning vocabulary mainly covered by the Educational Pathway, and prerequisite knowledge

Learning objectives:

Short description of the objectives of the described science learning experience

Guidance for preparation:

Guidance provided by the creator of the Pathway about any necessary arrangements that will need to be made by the interested teacher before launching the activities described in the following sections.

B) Pre-visit**Teaching Phase 1: Question Eliciting Activities**

- **Provoke curiosity:**

Describe ways and materials (resources already available in the CLEVERFOOD website, or other) that the teacher will present to the students in the classroom to attract their attention to the targeted subject matter. Make sure they are easily available to the interested user in the CLEVERFOOD website and give directions for finding them. Possibly and if appropriate, integrate them into one practical resource in the appropriate format (e.g. a slides presentation).

- **Define questions from current knowledge:**

Formulate the scientifically oriented questions that the teacher will present to the students to provoke their engagement in thinking about the target subject matter based on their existing knowledge. Make these questions digitally available and easily usable, e.g. by integrating them in the materials described in the previous step.

Teaching Phase 2: Active Investigation

Note: This is a transitional phase on the borderline between the Pre-visit and Visit sections of the Educational Pathway. 'Active Investigation', and in particular the step of 'Planning and conducting simple investigation' can take place either before or during the 'visit', or both, depending on whether the teacher decides to use open educational resources of an 'exhibit nature' (exhibits, simulations, experiments, etc.) at this stage (on the web or during a physical visit to a science museum/centre). However, the use of physical observation is concentrated mainly in the next Teaching Phase, under the 'Visit' section of the Educational Pathway.

- **Propose preliminary explanations or hypotheses:**

Describe ways in which the teacher can encourage students to propose possible explanations to the questions that emerged from the previous activity. The teacher should be guided here to identify



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

possible misconceptions in students' thinking. If applicable, locate or make relevant assistance materials available in the Virtual Pathway, and give directions for finding them. If appropriate, you may consider integrating them in the materials described in the previous steps (e.g. a slides presentation).

- **Plan and conduct simple investigation:**

Describe ways and materials (resources already available in the CLEVERFOOD website, or other) that the teacher can use to facilitate the students to focus on evidence as a source of answers to scientific questions. This is the phase in which students are being prepared for the subsequent phase of evidence gathering during observation. Locate or make relevant assistance materials available in the CLEVERFOOD website and give directions for finding them. If appropriate and relevant, it is possible to guide the teacher to use open educational resources of an 'exhibit nature' (exhibits, simulations, experiments, etc.) at this stage – in which case this activity should be moved to the 'Visit' section of the Educational Pathway. However, it should be noted that the use of physical observation is concentrated mainly in the next Teaching Phase of 'Creation', under the 'Visit' section of the Educational Pathway.

B) Visit

(Teaching Phase 2: Active Investigation)

Note: 'Active Investigation', and in particular the step of 'Planning and conducting simple investigation' can take place in either the Pre-Visit or the Visit phase of the experience, or in both, depending on whether the teacher decides to use open educational resources of an 'exhibit nature' (exhibits, simulations, experiments, etc.) at this stage (on the web or during a physical visit to a science museum/centre). However, the use of observation for gathering evidence is concentrated mainly in the Teaching Phase of 'Creation' described below.

Teaching Phase 3: Creation

- **Gather evidence from observation:**

This is the core element of the 'Visit' phase and can be realized either in the school classroom/lab, by remotely using science learning resources made available by the science museums/centres on the web, or during a physical visit which will involve the use of digital resources. Locate the appropriate resource in the CLEVERFOOD website. Explain its use to the teacher and provide access to any accompanying user support materials. The selected resource (e.g. a simulation, an experiment, an animation, a graph or other exhibit of similar nature) must provide students with an opportunity to collect evidence addressing the scientific questions posed in the previous stages through direct or indirect observation phenomena of the natural world. Provide guidance to the teacher organize and manage the activity most effectively and efficiently. It is recommended to introduce at this stage group work. Guide the teacher to divide students in groups, each of which will be facilitated by the teacher to formulate and evaluate explanations to the scientific questions based on the collected evidence. If applicable, locate or make relevant assistance materials available in the CLEVERFOOD website, and give directions for finding them.

Teaching Phase 4: Discussion

Note: This is a transitional phase on the borderline between the Visit and the Post-visit sections of the Educational Pathway. 'Discussion' can take place either during or after the 'visit', or both, depending on whether the teacher considers that the use of the digital 'exhibits' is necessary (or feasible) at this stage. Ideally, 'Discussion', and particularly the step of 'Explanation based on evidence', should take place in front



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

of the 'exhibit', to reinforce the link between the physical experience of using the resource and the mental processing of the observed information by the students.

- **Explanation based on evidence:**

Guide the teacher to provide the correct explanation for the researched topic. Describe ways and materials (resources already available in the CLEVERFOOD website, or other) she/he can use to this end, and give directions for finding them. If appropriate, integrate them into one practical resource in the appropriate format (e.g. a slides presentation).

- **Consider other explanations:**

Guide the teacher to facilitate the student groups to evaluate their own explanations in the light of alternative explanations, particularly those reflecting scientific understanding. Describe ways and materials (resources already available in the CLEVERFOOD website, or other) the teacher can use to this end and give directions for finding them. If appropriate, integrate them into one practical resource in the appropriate format (e.g., a slides presentation).

C) Post-visit

(Teaching Phase 4: Discussion)

Note: This is a transitional phase on the borderline between the Visit and the Post-visit sections of the Educational Pathway. Ideally, 'Discussion' should take place in front of the 'exhibit', to reinforce the link between the physical experience of using the resource and the mental processing of the observed information by the students. However, if necessary or preferred, it can also be organized as a post-visit activity leading into the next phase of 'Reflection'.

Teaching Phase 5: Reflection

- **Communicate explanation:**

Guide the teacher to facilitate each student group to reflect on the previous experiences and produce a report with its findings, presenting and justifying its proposed explanations to other groups and the teacher. Make available or direct to materials (resources already available in the CLEVERFOOD website, or other) which the teacher can use to help the students familiarize themselves with and become effective in scientific writing.

Follow-up activities and materials

Describe and direct the user to any follow-up activities or materials that can be used to 'wrap-up' the main 'visit' experience. These could include appropriate learning assessment and/or reminder materials (e.g. quizzes, games, other user-friendly tests), hints for further activities, suggestions for other relevant 'visits', etc.

Sustainable contact

Describe and direct the user to any existing possibilities for maintaining contact with the digital resource and its provider, or with other users of the same learning experience.



Educational Pathway Pattern for an Open Visit by Lifelong Learners

Among the possible Educational Pathway Patterns, the pattern for the description of open visits by independent informal learners can be seen as the simplest, least pre-defined learning experience examined in the CLEVERFOOD project. In this case, the museum educator/science communication professional, or even an experienced, motivated end-user, selects digital learning objects and combines them to form a meaningful, self-contained, user-friendly informal learning experience. The integration of resources scattered in various science museums/centres into the same learning experience is a priority (rather than selecting resources from a single museum or science centre).

A considerable degree of variation in the 'degree of structure' of the open pathway is expected to arise during the use of the CLEVERFOOD resources on the field, reflecting the varying degrees of user freedom in the context of informal science learning. In its extreme un-structured form, the open pathway can merely relate to random browsing and/or exploring of a set of aggregated learning objects. In such a case, implying any form of prescribed linearity of the experience should be avoided. More generally, the discussions within the CLEVERFOOD consortium clearly show a very strong culture among science museum and centre professionals which emphasise leaving the choice and order of activities or experiences totally open, with at least intervention as possible. This aspect of the 'open' visit should be deemed possible in the CLEVERFOOD tools, without being restrictive. It should be added that science museums and centres see the ways in which end users themselves will combine learning objects free of any interventions, as a valuable source of information about users' preferences and emerging understandings of the resources.

In this context, the pathway pattern for an open visit proposed in the following sections should be seen as an initial proposition to be tested. It should be technically realised in the most flexible way to accommodate the widest possible variety of approaches across the spectrum of formal and informal learning experiences.

The underlying pedagogical approach for the open visit

Although the Inquiry-Based Learning approach adopted for the description of structured educational pathways may well be relevant to open visits, too, it is felt that its structured nature may not correspond well with many of the possible formats of an open visit. Therefore, in this case the much wider Resource-Based-Learning conceptual framework (see in the third section of this document) is applied as the basis for the conception of the open visit. To allow for the highest possible flexibility, the present Pattern makes minimal use of different sub-phases, retaining however the basic organization in a three-step scheme of activities before, during, and after the 'visit'. The core of the learning experience constitutes the 'visit' phase, with 'pre-visit' and 'post-visit' being left optional to the discretion of the designer of the pathway.

The Educational Pathway Pattern for an Open Visit by Lifelong Learners

A) Introductory section and preparatory phase

The following basic information about the intended learning experience is to be defined at the outset. This information should allow the user to assess the relevance of the resource to his/her learning needs, preferences and circumstances, and provide him with guidance for the preparation of the learning experience. The formalisation proposed there for certain elements is to be applied accordingly in this introductory section too.

Title:

Give a title that helps easily recognize the content focus and purpose of the Educational Pathway.

Short description:



This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

A description of no more than 30 words outlining the scope of the Educational Pathway, descriptive enough to help the user in the first instance to estimate its possible relevance to her/his interests.

Keywords:

A limited number of words/short phrases reflecting the topic and scope.

Target audience:

The intended end user: independent informal learner, other...

Age range:

Up to 6, 6-9, 9-12, 12-15, 15-18, 18-25, 25+,...

Context:

The places that the Educational Pathway involves science museum/centre, independently on the web.

Time required:

The approximate time typically needed to realize the Educational Pathway.

Technical requirements:

Description of any special technologies, infrastructure and/or technical expertise required for the realization of the Educational Pathway.

Author's background:

What was the main function of the person who prepared the Educational Pathway: museum educator; parent; schoolteacher; other...

Science learning elements:

Reference to the items of the science learning vocabulary mainly covered by the Educational Pathway

Learning objectives:

Short description of the objectives of the described science learning experience

Guidance for preparation:

Guidance provided by the creator of the Pathway about any necessary arrangements that will need to be made by the interested user before launching the activities described in the following sections.

B) Pre-visit (optional)**Orientation information**

Describe and direct the user to any information available on the context and elements of the learning activity, which may prepare and orient the use before the 'visit'. Such information may typically be available on the web (e.g. on the museum's website), but in cases it may also relate to other media, such as TV programmes, printed materials (e.g. museum leaflets) etc.

Building pre-experiences

Describe and direct the user to any information or activities that might exist, and which would be a useful pre-experience preceding the main intended 'visit'. Such content may for example refer to other learning objects on the web, or, in the case of an open pathway addressing children and families, elements of the school curriculum which children should have some knowledge of.

Support or guidance available before the visit

This project has received funding from the European Union's Horizon Europe programme under grant agreement N° 101086320.

Describe and direct the user to any support or guidance mechanism or contact that may exist for the preparation of the 'visit'.

B) Visit (the minimal core of the learning experience)

Provoke curiosity: questions to ask, things to observe (optional)

Describe in simple terms the questions that the user could ask, or the observation or information he/she could concentrate on, during the 'visit' to get most of the learning potential offered by the experience. Direct the user to any relevant digital resources.

The core experience

Direct the user to the digital resources constituting the core of the 'visit' and describe in detail the way in which the 'visit' should be conducted, focusing on information that will help the user's orientation through the resources involved. If appropriate, explain the rationale behind the proposed ordering of the activities, or state and explain the freedom in which the learning experience can be shaped by the user.

Support or guidance available during the visit (optional)

Describe and direct the user to any support or guidance mechanism or contact that may exist to support the 'visit' in real time.

Any other relevant information (optional)

Provide any other information that does not fall under the previous categories but is necessary or useful for the effective / efficient realisation of the 'visit'.

C) Post-visit (optional)

Follow-up activities and materials

Describe and direct the user to any follow-up activities or materials that can be used to 'wrap-up' the main 'visit' experience. These could include appropriate learning assessment and/or reminder materials (e.g. quizzes, games, other user-friendly tests), hints for further activities, suggestions for other relevant 'visits', etc.

Sustainable contact

Describe and direct the user to any existing possibilities for maintaining contact with the digital resource and its provider, or with other users of the same learning experience.

