I SEE start-up module on climate change

I SEE

It's your time to imagine the futures

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General introduction to the module

This module includes all the materials that have been implemented during the I SEE summer school, occurred in Bologna, June 5-9, 2017.

The following table report the timetable of the school and shows the articulation in three “blocks”, respectively aimed to develop: a) conceptual & epistemological knowledge and skills; b) future-scaffolding skills; c) action competence and agency. The three blocks have respectively developed by the Finnish, the Italian and the Icelandic Communities of Practice. Besides the three blocks, the I SEE partnership organized events, during the summer school, that were targeted to a wider audience: two plenary lectures by Carlo Cacciamani and Peter Bishop, a Panel with experts on climate change.

	mo. 5.06.2017	tue. 6.06.2017	wed. 7.06.2017	thu. 8.06.2017	fri. 9.06.2017
09:00		Conceptual & Epistemological activities – SLOT 3 (CE-3)	Future-scaffolding skill activities – SLOT 1 (Fut-1)	Panel with experts: Bonoli, Di Sabatino, Morelli, Wilson	Action competence activities – SLOT 4 (AC-4)
09:30					
10:00	Opening ceremony				
10:30	Plenary lecture Prof. Cacciamani on CC				
11:00		Conceptual & Epistemological activities – SLOT 4 (CE-4)	Future-scaffolding skill activities – SLOT 2 (Fut-2)		Presentation of the final products
11:30				Action competence activities – SLOT 1 (AC-1)	
12:00	Plenary lecture Prof. Bishop on Future studies				
12:30					Closing ceremony
13:00					
13:30					
14:00	Conceptual & Epistemological activities – SLOT 1 (CE-1)	Free time (to visit Bologna)	Future-scaffolding skill activities – SLOT 3 (Fut-3)	Action competence activities – SLOT 2 (AC-2)	
14:30					
15:00					
15:30					
16:00	Conceptual & Epistemological activities – SLOT 2 (CE-2)		Future-scaffolding skill activities – SLOT 4 (Fut-4)	Action competence activities – SLOT 3 (AC-3)	
16:30					
17:00					
17:30					
18:00	Welcome Party				
18:30					
19:00					
19:30					
20:00					

The current version of the Start-Up module will be revised in the light of the research results we will obtain from the data analysis and will be simplified to be used in school contexts more usual than an International summer school.

Part 1 – Conceptual and epistemological knowledge (Helsinki group)

Learning outcomes

- Students learn to model greenhouse effect as a scientific phenomenon.
- Students will learn (or revise) the physical concepts of radiation, heat, temperature, interaction between matter and electromagnetic radiation, atmosphere of the earth (contents and function), greenhouse gases and global warming.
- Students learn scientific epistemology and lab working skills: modeling phenomena, testing hypotheses, making predictions, observing, planning, and executing controlled experiments and measurements, analysing data, communicating findings to peer groups, forming arguments on the basis of empirical findings.
- Students practice modelling and argumentation (*transversal future-scaffolding skills*).

Overview:

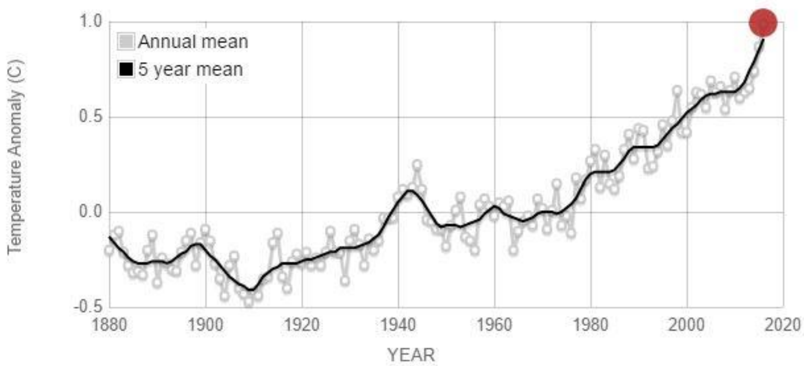
Completing all the activities in Part 1 with students will take approximately one working day. Time should be allocated also for cleaning up after every labwork.

The activities are designed to support students' own activity and discussion. The emphasis is on student centered modeling, which aims to link the concepts of greenhouse effect to the previous knowledge.

Introduction

1. Discussion about the global temperature

   Students are shown the following picture.



https://climate.nasa.gov/vital-signs/global-temperature/

Students are asked to discuss the following questions:

- What is the global temperature?
- What does the graph tell us?
- What causes the rise of the global temperature?

2. Students are asked to explain in small groups (3-4 students):
   - What does greenhouse effect mean?
   - How does it work?

     Students can for example draw a picture or a mind map, or explain their ideas and views about the greenhouse effect by other means. The purpose of this activity is to find out students' initial understanding and knowledge about greenhouse effect.

Activities

Activity 1

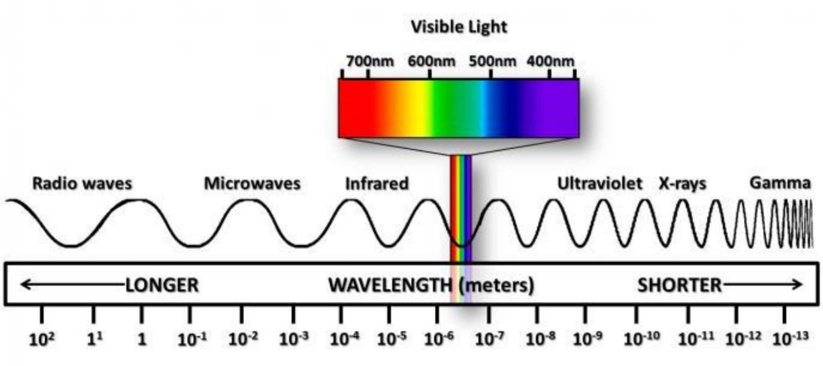
The purpose of this activity is to introduce to the spectrum of electromagnetic radiation.

- Materials:

  - spectrophotometer, compatible interface and software
  - a variety light sources; for example LED, incandescent bulb, sun

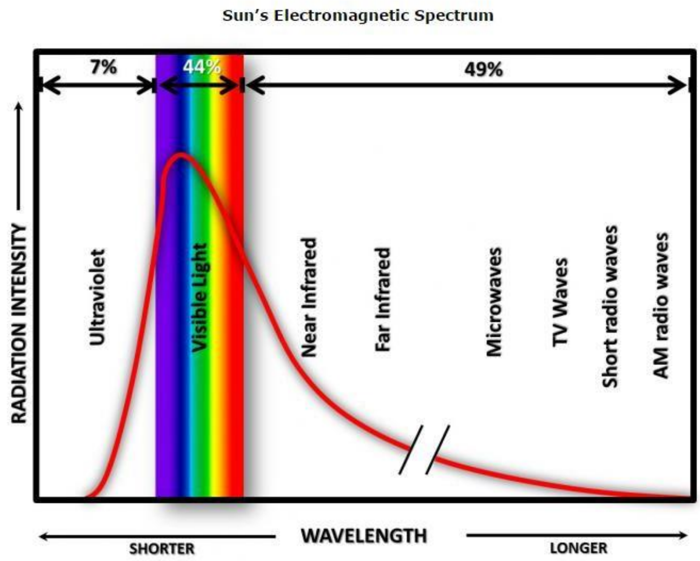
- Spectra of various light sources are measured using the spectrophotometer and the differences are discussed.

- A picture of the electromagnetic spectrum is shown. It is reminded and discussed that visible light, which was measured earlier, only represents a narrow part of the complete range of electromagnetic radiation.



http://www.ces.fau.edu/nasa/module-2/radiation-sun.php

- Another picture of the sun's electromagnetic spectrum is shown. The picture shows how much of the electromagnetic radiation emitted by the sun falls within ultraviolet, visible light and infrared wavelengths.



http://www.ces.fau.edu/nasa/module-2/radiation-sun.php

Activity 2

The purpose of this activity is to learn that visible radiation is absorbed by the Earth's surface which in turn emits thermal radiation.

- Materials:

  - Two Erlenmeyer flasks with stoppers with one hole
  - black paper, aluminum foil
  - two thermometer probes, compatible interface and software
  - tape

Place two Erlenmeyer flasks in sun light. Place black paper in the bottom of one flask and aluminum foil in the other. Add some tape to the flasks to prevent the sun light to heat the probes directly. Measure the temperature of the flask as shown in the picture. The results of experiments are discussed.

- Expected results: The temperature in the flask with black paper rises more than in the flask with aluminium foil. Students should learn that visible radiation is absorbed by black paper. This warms up the paper which in turn emits thermal radiation (infrared radiation). The air in the flask gets warm due to this thermal radiation and the heat conducted from the paper to the air. The air in the other flask will also get warmer, but due to reflection of light the temperature of the paper – and, thus, the air – does not increase as much as in the other flask. The concept of albedo can be discussed in touch with this experiment. Albedo refers to the fraction of radiation reflected back. Surfaces for example ice that have a high albedo reflect more solar radiation than dark surfaces which have low albedo.

Activity 3

The purpose of this activity is to learn that some gases absorb infrared radiation.

- Materials:

  - infrared thermometer (IR gun)
  - tube, for example gutter pipe, in T-shape
  - a hot object, for example a hot plate
  - an experiment stand to hold the tube and the thermometer
  - an Erlenmeyer flask
  - baking soda, vinegar (for preparing carbon dioxide)

- boiling water

First the principle of the infrared thermometer is discussed. In short: the thermometer can determine the temperature of an object by measuring the thermal radiation emitted by the object.

Fasten the tube and the infrared thermometer on a stand. Place the hot plate so that its temperature can be measured with the thermometer through the tube. Heat the hot plate till a certain temperature. Measure its temperature first through air in the tube.

Pour some vinegar in the Erlenmeyer flask and add some baking soda. Quickly place the flask in the hole under the tube. The carbon dioxide produced in the flask will fill the tube. Measure the temperature of the hot plate again before carbon dioxide escapes the tube.

Then place a beaker with boiling or hot water in the hole under the tube. Repeat the measurement when the tube is filled with water vapour.

Finally place a glass plate between the hot plate and the thermometer and measure the temperature.

- Expected results: The thermometer shows the temperature of the hot plate to appear lower when measured through carbon dioxide or water vapour or behind a glass plate. The explanations of these results are discussed with students. The temperature of the hot plate obviously is constant, but it appears to be lower because carbon dioxide, water vapour and glass prevent thermal radiation to pass through like in air. Part of the infrared radiation is absorbed by carbon dioxide and water vapour which are greenhouse gases.

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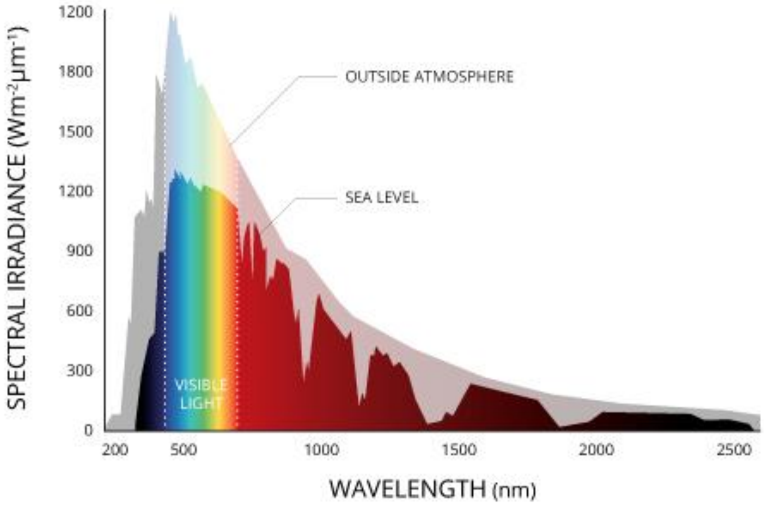
This activity can be extended by infrared pictures. If an infrared camera is available the following kind of pictures can be taken. They illustrate how, for example, glass is transparent to visible radiation but nor for infrared radiation. On the other hand, light does not pass through a black plastic bag, but infrared radiation does.

Finally, in this activity a picture of the spectrum of solar radiation is shown again. This picture shows the difference between the radiation outside atmosphere and the radiation that reaches Earth's surface. The visible wavelengths of radiation are passed through the atmosphere more easily than the longer wavelengths which are absorbed by the greenhouse gases.



http://www.fondriest.com/environmental-measurements/parameters/weather/photosynthetically-active-radiation/

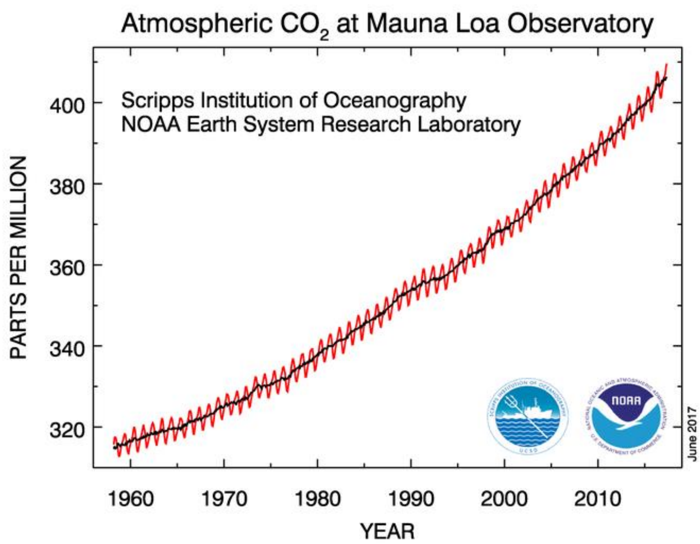
After the three activities, students are asked to revise their initial explanations about the greenhouse effect. Students represent their explanations to each other.

If there is need to recapitulate the principle of the greenhouse effect, a video can be watched:

https://www.youtube.com/watch?v=sJ0eN_93l4k

Activity 4

As an introduction, a graph is shown that shows the atmospheric carbon dioxide concentration measured in Mauna Loa Observatory.



https://www.esrl.noaa.gov/gmd/webdata/ccgg/trends/co2_data_mlo.png

The purpose of this activity is to explore how different objects affect the concentration of carbon dioxide.

- Materials:

- a carbon dioxide probe, compatible interface and software
- a glass beaker
- a lid with a hole
- a candle
- bananas, grapes
- freshly cut leaves
- water
- soda water
- aluminum foil or black canvas to cover the beaker

Place a candle in the glass beaker. Put a metal lid and a carbon dioxide probe on the beaker. Light the candle and measure the concentration of CO_2.

Take off the candle and shake both the beaker and the probe to ventilate them. Continue the measurements with bananas, grapes, water etc. placed in the beaker. When measuring the concentration of CO_2 with green leaves such as parsley, put the beaker first in sun light or a bright light for example an old slide projector. Then cover the beaker with aluminum foil or black canvas and continue the measurements. If you have a motor to circulate the air in the beaker the CO_2 will divide more evenly in the beaker. Also, the beaker can be placed inclined as in the picture below. Remember to be patient with these measurements.

Activity 5

The purpose of this activity is to expand the previously acquired knowledge of carbon emission to concern also anthropogenic sources.

- Materials: Computers or mobile devices for the students.

Watch an introductory video of the carbon footprint, for example: https://youtu.be/8q7_aV8eLUE

In small groups (3-4 students), students are asked to calculate their own carbon footprints using a calculator available on the internet. For example, http://web.stanford.edu/group/inquiry2insight/cgi-bin/i2sea-r2b/i2s.php?page=fpcalc

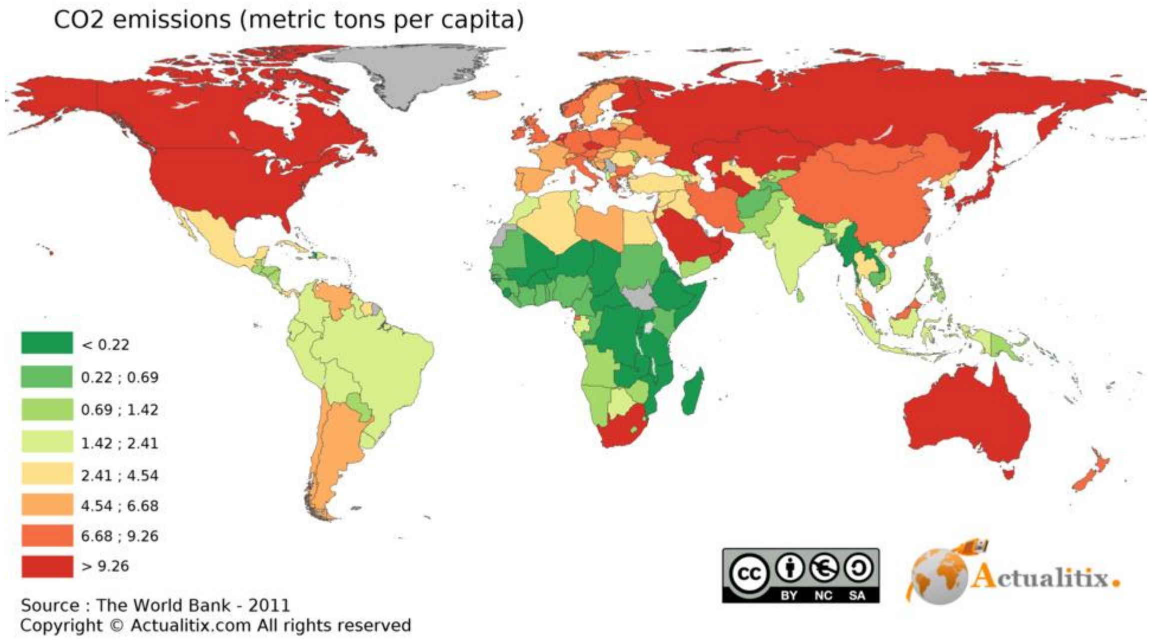
After that, they discuss the following topics:

- What is the largest carbon source in the life of an adolescent in my country? Why?
- How could we reduce our footprints?
- Is there some particular carbon source for reduction of which we already do pretty good job?

Teacher led discussion of topics:

- What differences in carbon emission we noticed?
- How do our footprints relate to the global average?
- Can we affect the global picture?

For example, this picture can be used to facilitate the closing discussion of the global viewpoint:



https://en.actualitix.com/country/wld/co2-emissions-per-capita.php

Learning outcomes

The learning outcomes of the activities are summed up in Table 2.1. They are related to each of the three set of activities in which this part is organised. Although the activities have been designed with a multidimensional approach that often strictly links knowledge and skills, for each learning outcome, we specify what type of knowledge and/or skill is *mostly* involved. The distinction between content, procedural and epistemic knowledge is inspired by the OSCE-PISA recommendations (OECD, 2016; PISA, 2015).

Table 2.1. Learning outcomes of the three sets of activities with the related knowledge and/or skills that are mostly involved.

Set of activities	Learning outcomes	Knowledge and/or skills mostly involved
A	Students get acquainted with basic concepts of science of complex systems: complex system, nonlinearity, sensitive dependence on initial conditions (butterfly effect), self-organization, circular causality, positive and negative feedback loops.	Scientific content knowledge
	Students become familiar with one of the main tools of the science of complex systems, the simulation, and understand that it can be considered a third way to study phenomena beyond the two traditional ones (laboratory experiments and theories); they learn that the simulation does not use normal words or symbols of mathematics but uses a particular language that incorporates into a computer program that can be used as a virtual laboratory.	Scientific procedural knowledge
	Students recognize that linear causality is not the only way to think and talk about the future and get acquainted with a new vocabulary elaborated by the science of complex systems to think and talk about future (e.g. the concept of projection as distinct from deterministic prediction; the concept of possible future scenarios).	Scientific epistemic knowledge
	Students learn that approaching science phenomena that involve citizenship issues (e.g. climate change) implies a change in the epistemological way of looking at the phenomena itself: they learn, for example, that climate is a complex system and that the interpretation of phenomena related to it implies new type of explanation, modelling and argumentation.	Scientific epistemic knowledge
B	Students become able to analyse scientific texts by recognizing the causal net made by links and nodes.	Ability to analyse and understand written texts
	Students become able to distinguish from linear and circular causality, within the scientific texts, recognizing the nature of the causal links and individuating possible feedback loops that can be found starting from the text.	Abilities to: explain phenomena scientifically; manage the three-pronged knowledge (about the concept of feedback and of causality) to reason about the future
	Students learn to transform the causal nets present in the scientific texts into cause-effect maps.	Ability to build causal maps

C	Students become able to apply concepts of science of complex systems (e.g. feedback loop) in an urban problem. Students learn that approaching climate change implies a change in ways we live in everyday life and we, collectively, make decisions. Students get acquainted with basic concepts coming from future studies (forecast, foresight, anticipation, back-casting, the distinction between probable, possible and desirable futures) and manage these concepts to reason about an urban problem. Students learn that scenarios are hypothetical sequences of events constructed for the purpose of focusing attention on causal processes and decision points and practice for elaborating them. Students become able to imagine possible future careers to aspire, putting their creativity into play. Students become personally committed to outline a desirable scenario and/or to point out a desirable objective to be reached in the future. Students take the agency to plan an action to make their futures possible. Students work in group to reach shared decisions.	Ability to explain phenomena scientifically; manage the three-pronged knowledge (about the concept of feedback and of causality) to reason about the future Decision making skills Ability to manage the distinction between possible, probable and desirable futures Knowledge about the concept of scenario Creativity Active participation Plan actions Cooperation and conflict resolution skills

Overview

The activities aim to develop future-scaffolding skills (both scientific and transversal).

They are articulated in three different types for a total of 8 hours:

a. Activities on Future-scaffolding hard-scientific skills (2h hours and half), focus on science on complex system and the use of simulations;
b. Activities on Future-scaffolding transversal skills from *Logical Framework* (2h hours and half), focus on an example of mitigation within climate change (transport) and the construction of causal maps from the analysis of a scientific text;
c. Activities on Future-scaffolding transversal skills from *Futures Studies* (one task to do at home - half an hour + 3 hours), focus on the analysis of a societal problem and the creation of future scenarios

As an intermediate part of the module, it represents the link between the other two. This part is strictly content-dependent with regard to activity A and B, instead it is content-independent with regard to activity C.

Activities

Activity 1 (A)

The first set of activities has the main goal to *develop hard-scientific knowledge about the science of complex systems*.

- **Needed materials**

Paper and pencils to take note

iPad or laptop (1 per group) for the simulations

- **Description of the specific activity enriched also by practical suggestions for the teacher (e.g. how groups should be made, what types of questions, why you ask that and where you can find resources for the answers)**

The teaching strategy is a dialogic lecture, where the structure of the lecture is part of the message that the materials intend to vehicle. The new concepts and the new terms are indeed part of a general framework that outlines an epistemological change in the way science models changes and manage the future, overcoming and problematizing the linear deterministic Newtonian causal modelling.

- **How the activity runs**

The activity focuses on the concepts of science of complex systems. This discipline has been chosen because the approach to climate study requires a change in the epistemological paradigm, which becomes very different from the one used in classical physics. Indeed, the linear, deterministic and reductionist paradigm - though being the most taught in school physics - is not the only one that authentic physics has provided and the science of complex systems gives interesting inputs to develop new ways of thinking about causality, modelling strategies, systems, elements which are all fundamental if one wants to approach to the study of climate science.

The science of complex systems laid the foundations of a completely new paradigm of causal explanation. The most fundamental concept is the renounce at linear causality in favour of the recognition of the existence of a circular pattern of causality, mainly represented by the concept of feedback. As a consequence, complex systems can show a high sensitivity to initial conditions, since at small variations in causes can correspond big modifications in effects (the so called 'butterfly effect'); this weakens the possibility to obtain a determinist prediction about the future because the non-linear equations, rather than conserving the unavoidable experimental errors on initial conditions, can progressively amplify them (deterministic chaos). As a consequence of this reasoning, the term 'prediction' itself – referring to the univocal result of the application of a model – loses significance beyond a little time horizon. Therefore, instead of 'prediction', a more used term is 'projection' because it indicates the range of possibilities which is as wide as many and various are the future scenarios obtained from the application of a model. A crucial word for the study of climate systems, as complex ones, is properly the term 'scenario' and it means not a specific prediction about future but a plausible description of what could happen, based on trends and events obtained from the past and from the present.

Another characteristic that is no more valid in many complex systems is the additivity of causes in leading to an effect. The need of a change of paradigm arises from the existence of phenomena of self-organization, spontaneous processes where some form of overall order arises from local interactions between parts of the system. Within this perspective, the reductionist paradigm fails too: in complex systems, understanding the individual components is crucial but the knowledge of the parts is not sufficient in order to explain the behaviour of the whole system; the complex interactions between parts create new processes, principles and structures that, although having their material basis on the underlying components, are conceptually independent from those.

This activities aim to explore the main concepts of science of complex systems and are characterised in terms of disciplinary content, application context and form of presentation of the activities themselves (cfr. Table 2.2 for an overview). Content, context and form of presentation are systematically confronted against the Newtonian paradigm.

Table 2.2. Overview of activities A.

Activity	**Disciplinary content**	**Application context**	**Form of presentation**
Lotka-Volterra predator-prey model	non-linearity	ecological science	mathematical description and simulation
Feedback Ted-Ed lesson	feedback and circular causality	ecology, climatology, economics, computer science, molecular biology	video-lesson and interactive test
Schelling's segregation model	self-organization and emergent properties	sociological modelling	simulation

The first activity focuses on the concept of non-linearity through one of the simplest model in complex systems science. It describes the variation of number of preys and predators, if specific conditions hold. In order to present this model (also known as Lotka-Volterra) the following strategy is suggested: first of all, the mathematical equations are verbally presented and commented, in order to explain the meaning of the variables and the modelling role of the various coefficients, as showed in Figure 2.1.

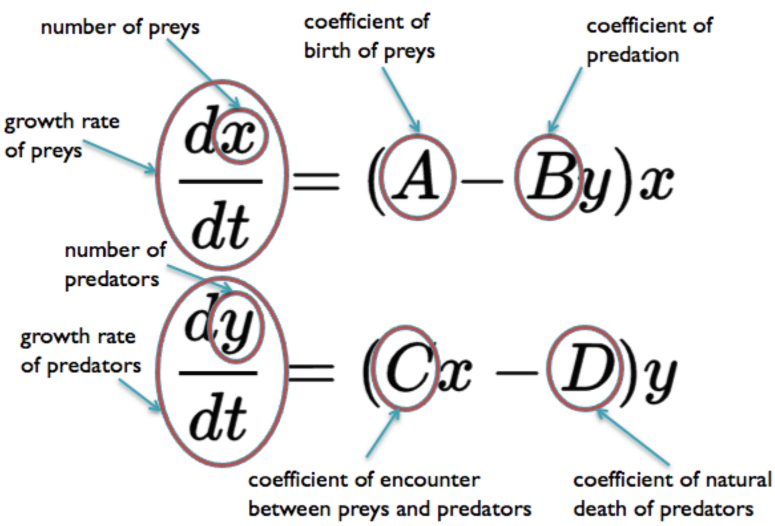


Figure 2.1. Equations of the Lotka-Volterra model in which the names of the variables and the parameters are made explicit.

Secondly, to make students "see" the mode of operation of the model, a simulation is presented: http://mathinsight.org/applet/lotka_volterra_versus_time_population_display. Changing the values of the parameters A, B, C and D, the simulation gives two graphs, like the ones in Figure 2.2, representing the evolution of prey and predator populations.

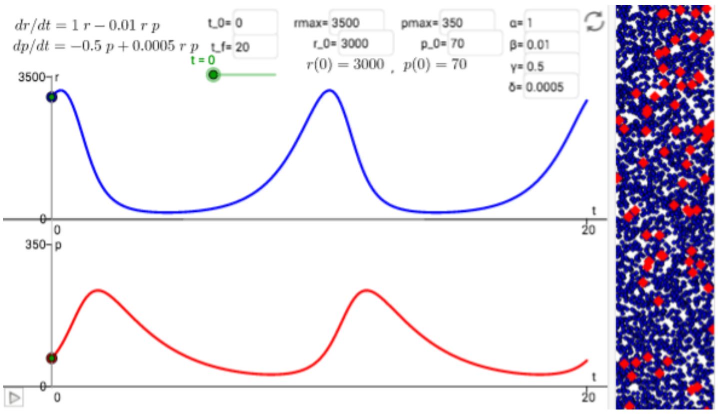
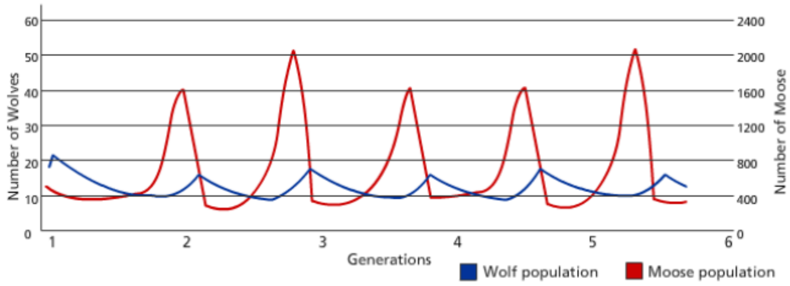


Figure 2.2. Graphs of the time-evolution of prey (blue) and predator (red) populations, according to the Lotka-Volterra model, with a suitable choice of parameters A, B, C and D.

After this phase of the activity, the results of the simulations are compared with the real data coming from the observation of a real predator-prey relationship, considering the interaction between wolves and moose on Isle Royale, an island in Lake Superior. Showing the difference between the two graphs, here reported in Figure 2.3, it is pointed out that all models, through all the possible improvements with the addition of other coefficients, can never take into account the whole complexity of the real world. To clarify this point, a second simulation, available online at the link http://www.phschool.com/atschool/phbio/active_art/predator_prey_simulation/, is showed. It allows students to change some more parameters which soften some validity conditions of the model.



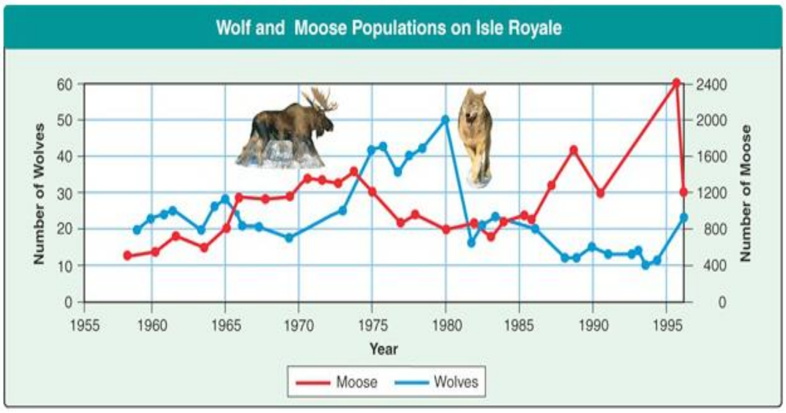


Figure 2.3. Comparison between ideal and real graphs: 2.3.top) ideal graph obtained with the application of the Lotka-Volterra model, with fixed parameters; 2.3.bottom) real data for 40-years evolution of wolf and moose populations on Isle Royale.

So, to recap the design aspects of this activity, we have: i) a disciplinary content represented by the non-linearity between variables in a complex system, ii) an application context within the ecological science and iii) a form of presentation that uses a simulation that allows the student to "play" with the different parameters of the model.

The second activity focuses on the concepts of feedback and circular causality as crucial aspects that characterize a complex system. The activity is a sort of follow up of the previous activity. Its main goal is to refine vocabulary, ideas and arguments in order to examine more and more deeply and consciously the sense of giving up linear causality when talking about complex systems. The activity is organized as a TED-Ed page, based on an animated video-lesson: http://ed.ted.com/lessons/feedback-loops-how-nature-gets-its-rhythms-anje-margriet-neutel#watch. The topic is positive and negative feedbacks in biological systems. Using a musical metaphor, the video gives imaginative tools for thinking the raising up of self-organization starting from a complex substrate of feedback cycles.

The video-lesson is equipped with different kinds of questions (multiple choices or open-ended), to boost on-line learning about the topic; the questions asked to students are reported in Annex A4. Moreover, there is a summary about the contents of the video, with some details for a deepest analysis of the topic (links to other Ted-Ed lessons, to scientific papers, etc.). It has also been created a section for discussion, where everyone can leave questions, comments or remarks that all participants can read and answer.

For the activity, we suggest to watch the video twice. The first time students can be asked to focus their attention in order to identify the keywords of the topic that emerge from the video (e.g. feedback as mutual causal interaction, stable balance, ongoing process, …). For the second time, students can be asked to give significance to the sentence "*feedback is what makes everything work*", focusing students' attention on the fact that positive and negative feedback are powerful forces that shape the behaviour of all biological systems: negative feedback provides stability, while positive feedback stimulates change and is responsible for the sudden appearance of environmental problems and many other rapid changes in the world.

At the end of the interactive lesson, the activity is supposed to be completed by a classroom discussion of other types of feedback that can be recognized in a lot of fields of interest. In our implementation, we chose the example of the relationship between atmosphere absorbance and the growth of the temperature at the Earth surface (climatology), the law of supply and demand (economics), the violation at central dogma of molecular biology (molecular biology) and the selection bias (computer science).

So, to recap the design aspects of this activity, we have: i) disciplinary content represented by the concepts of feedback and circular causality, ii) an application context that embraces different areas of interest (from ecology to climatology, from economics to computer science) and iii) a form of presentation that uses a video-lesson, an interactive test to verify the knowledge acquired and a classroom discussion to share examples and what was learnt.

The third activity of this set regards the concept of self-organization. It uses a method that is itself a disciplinary content of complexity science: the simulation. For many reasons, it is practically impossible to study complex social systems through the experimental technique: we think about the great difficulty in manipulating deeply woven variables (the adjective 'complex' has properly this etymology: cum-plexus, woven together), but we also think about the ethical consequences of such an approach; because of these reasons, simulations are used, in which one can replicate, through a specific software, the principal properties and the dynamics of a social system and, through the controlled manipulation of some reference materials, one can perform "experiments". The "playable post" presented for this activity refers to the Thomas Schelling's dynamic model of segregation and is available at link http://ncase.me/polygons/. In this model, the environment is a 2-dimensional world populated by squares and triangles, in which simple cohabitation rules convert themselves in scenarios of racial segregation.

This last aspect allows us to see how, in complex systems, to causes at the level of individuals and their interactions can correspond effects at the level of system. We confer on this activity an important role because we want, in our research, to build agency skills that can be acquired only if there is a comprehension of the fact that one can do something and that his/her personal action does make the difference.

So, to recap the design aspects of this activity, we have: i) a disciplinary content represented by the concept of self-organization and sensitivity to initial conditions, ii) an application context that refers to a model very well studied sociological model and iii) a simulation as form of presentation.

- **Possible difficulties that students and teachers can encounter.**

In the activity about Lotka-Volterra model, students can encounter difficulties in dealing with the mathematical equations, written in differential form. Teachers can introduce the model even if students have not yet studied derivatives in mathematics course, explaining that the symbol dx/dt means the increase of the quantity x (which is the population of predators or preys) in the time interval t; if the population increases, dx/dt is positive, while if the population decrease, it is negative.

In the activity about feedback, it must be paid attention to the fact that the term 'negative' and 'positive', in many current languages, recall the meanings of 'bad' and 'good' respectively. Teachers have to take care of the correct students' understanding about this. Moreover, it is important to focus students' attention on the fact that negative feedback loops provide a *dynamical equilibrium* of mutual interacting elements: this can enrich the students' idea of equilibrium, that is not only a static concept but can be the result of a complex dynamism.

In the activity about self-organization, the main difficulty that students can encounter is about the concept of simulation, which is, in some cases (like social systems as in the Shelling's model), the only way we have to study complex systems. Teachers have to support students in dealing with this important tool, highlighting the its modelling aspects.

- **Expected results (just in case we want to present examples of students' outputs)**

Students' outputs with regard of this set of activities are the discussions during the interactive lesson.

A more concrete output can be required to students in the activity about feedback: indeed, the TED-lesson which follows the video is equipped with a set of questions (multiple choices and open-ended) that students can answer, so that teachers can control their students' advancements in the understanding of the topic.

- **Annexes and/or suggested sources**

Slides and/or video about the lecture

Links to the simulations

Activity 2 (B)

The second set of activities has two main goals: to develop i) *hard-scientific skills about the science of complex systems,* like recognizing and imaging feedback loops; ii) *transversal skills,* like reading, analysing a scientific text and building causal maps. The activity is made up of five different parts that consist of 5 specific tasks which are explained in the following.

- **Needed materials**

Paper and pencils

Worksheets (1 per each student)

iPad (1 per group) for the data collection

- **Description of the specific activity enriched also by practical suggestions for the teacher (e.g. how groups should be made, what types of questions, why you ask that and where you can find resources for the answers)**

The activity is supposed to be orchestrated by the teacher with the following pace: give a task, leave the students work in their group, discuss the task all together and then introduce a new open issue/question related to the new task. The students are free to form the group by themselves.

- **How the activity runs**

The activity is framed within the issue introduced in the previous activity and aims to go in depth into the concepts of feedback and circular causality by analysing a scientific text focus on a specific case about biofuels.

The activity is introduced by stressing that, according to the IPCC report (2014), there are many anthropogenic causes that play a crucial role in the domain of greenhouse gas emissions, among which food consumption (e.g. related to agriculture and livestock farming), energy consumption (e.g. related to electricity and heat production) and transports (see fig.2.4).

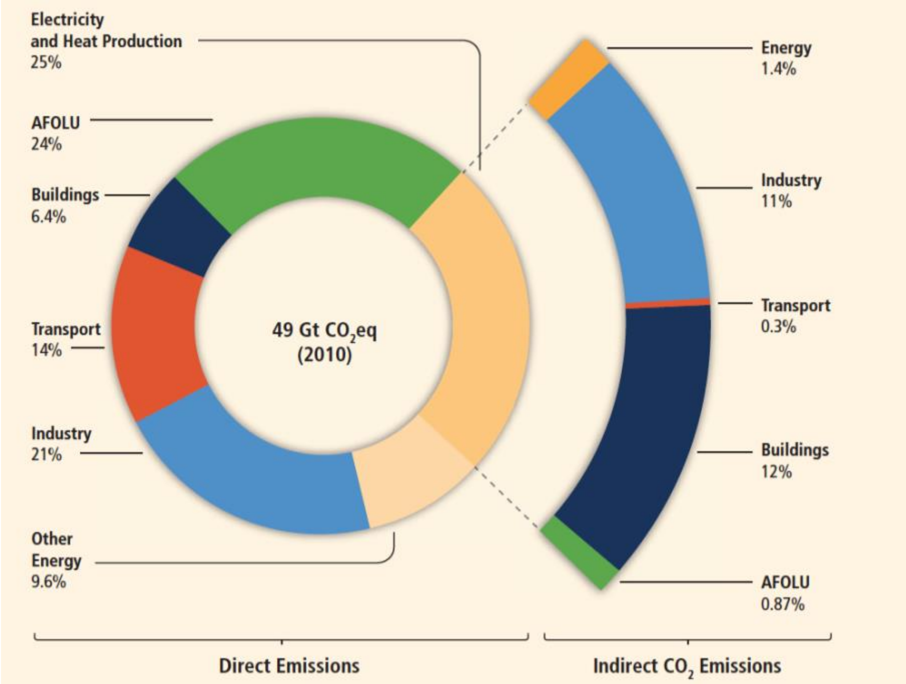


Figure 2.4. Greenhouse Gas Emissions by Economic Sector (IPCC, 2014).

The activity is situated in this framework and zooms in on the transport sectors and, more precisely, on the area concerning bio fuels and biodiesel.

The core of the activity is the scientific text named the 'Biodiesel Story' (Annex ??). The text is organized in three parts: the first one is an introduction about transports in general, the second one is about the use of biodiesel and the third one is about the production of biodiesel.

The text has been written by the researchers of the Italian group with a clear objective: to offer the students a text on which they can exercise to recognize and abstract the logical and causal structure of the phenomena described in it.

Although the fact that the issue of biofuels is often treated in terms of pros and cons, advantages and disadvantages, the text is written to avoid mentioning these words, limiting the text to detail the cause-effect relationships, without making it too explicit (in the sense, that we avoid using expressions like 'this causes this'). The text presents a lot of notes for an in-depth analysis about the chemical details and the technical terms that comes from climatology. These notes are intended to be to completion with respect to the text: it is readable and comprehensible also without reading them. A particular attention, along the whole text, is given to the references[1].

The activity consists of reading the Biodiesel Story and to build a map that summarizes the cause-effect net that the text displays. Our proposal of map is reported in Figure 2.5 and in Annex ??.

1 After we drafted the text, we asked two experts, Prof. R. Rizzi and Prof. Margerita Venturi, to check and validate the contents. Readability by secondary school students has been instead checked by secondary school teachers, Prof. Michela Clementi, Paola Fantini, and Fabio Filippi.

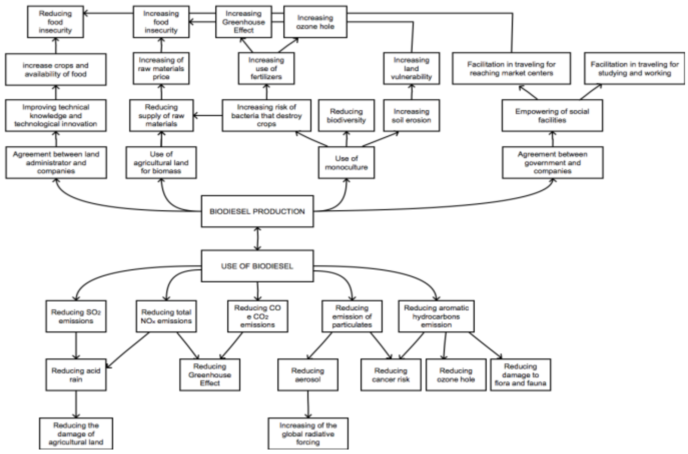


Figure 2.5. Our proposal of map drawn starting from the text of the "Biodiesel Story" (see Annex ??? for an enlarged version).

In it, two main areas are identified: one is related to the use of bio diesel, while the other is related to its production. The arrows indicate the different levels of causality.

In order to guide the students in this work, the first task is to read the part of the text titled "Use of Biodiesel" and draw the map by giving a starting map to complete (Figure 2.6).

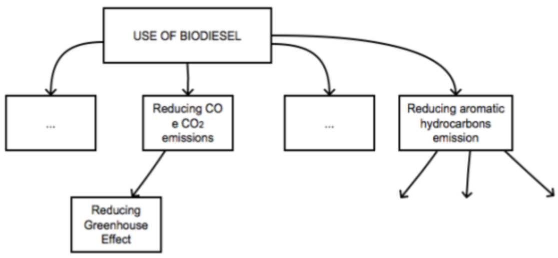


Figure 2.6. Piece of map to be completed (see Annex ??? for an enlarged version).

The construction of the map is not particularly difficult but requires some time to enter the logic of reading a text and to identify the causal nexuses in the structure. For this reason, it is important to give an initial piece of the map, just to show some examples of what it is meant by causal links.

The second task consists of giving the students the complete map built on the text "Use of biodiesel", asking them to compare it with the map they have drawn and discussing on differences and similarities in the links. A final collective discussion after this task is required in order to share different thoughts, doubts, questions, interpretations and/or difficulties and arrive at a sharing view of the first part of the map. After that, the third task is introduced and consists of giving the whole map of the "Biodiesel story" to be looked at, by using the *lens* of causal links (Selection of the problem, not a list and not chronological).

The fourth task is to read the text about the production of biodiesel and compare it with the map related to the production (Figure 2.7).

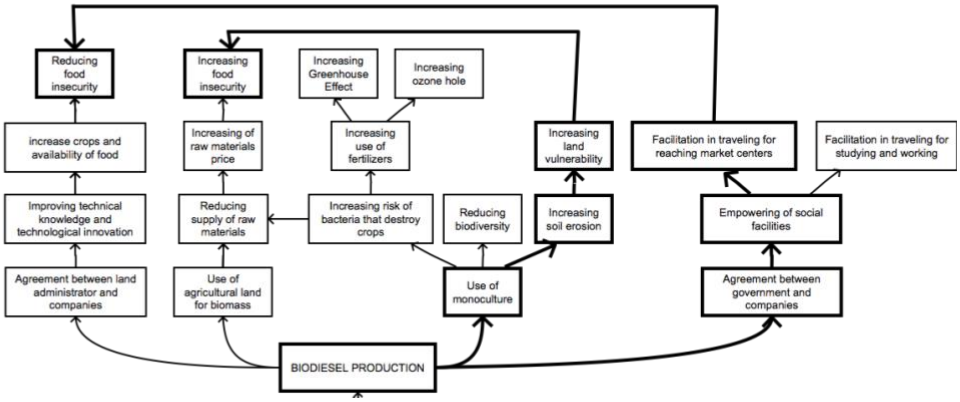


Figure 2.7. Map related to the production of biodiesel with some links highlighted (see Annex A?? for an enlarged version).

The map given to the students have two crucial links highlighted. Indeed, the other part of this task is to explain the causal reasoning represented by the arrows that go from the biodiesel production to the increasing/reducing of food insecurity through: i) the increasing of land vulnerability; ii) the facilitation in travelling for reaching market centres.

This task let to go from the map to the text and to make explicit two reasoning beyond causal chains which lead to two opposite aspect. Even after this task, a final collective discussion is required in order to share different thoughts, doubts, questions, interpretations and/or difficulties and arrive at a sharing view of the second part of the map. Not only, at this point is important to see the different dimensions involved the issue and started to positioning with respect to what it is important for whom and start to take into account personal sensibilities and values. This collective discussion is important for two main points: i) to check if students have understood the sense of a causal map (not a summary and not a list); ii) to stress the importance of carrying on the problem analysis before put into place the values.

Until now, the activity was focused on particular cause-and-consequences relationships which were “direct relationships”. Indeed, this initial map is a linear one: starting from a cause, the consequence follows, then it becomes cause of another thing and so on. After this first part of the activity, in which the scientific text is organized into a logic map, the mechanism of feedback is introduced, showing that, in this linear map, some links can be enriched if one considers the underlying feedback loops. Two examples are given in order to explain what it is meant.

The fifth task has been designed in order to build a proper skill about the concept of circular causality. Two schemas of feedback loops (see Annex ???) related to the map are delivered to the groups and two requirements have been asked. The first one consists of considering the scheme of feedback loops they received, provide a detailed description of the phenomena summarized in the schemes and situate the loops in the map of the biofuel issue. Our proposal of map, in which all the feedback areas are highlighted, is reported in Figure 2.8 and in Annex ??. The second one consists of the request of finding in the map (preferable) other possible loops, one positive and one negative, different from those given in the previous phase, related to the issue; students are asked to detail the loops found in an extended way and to represent them in a scheme.

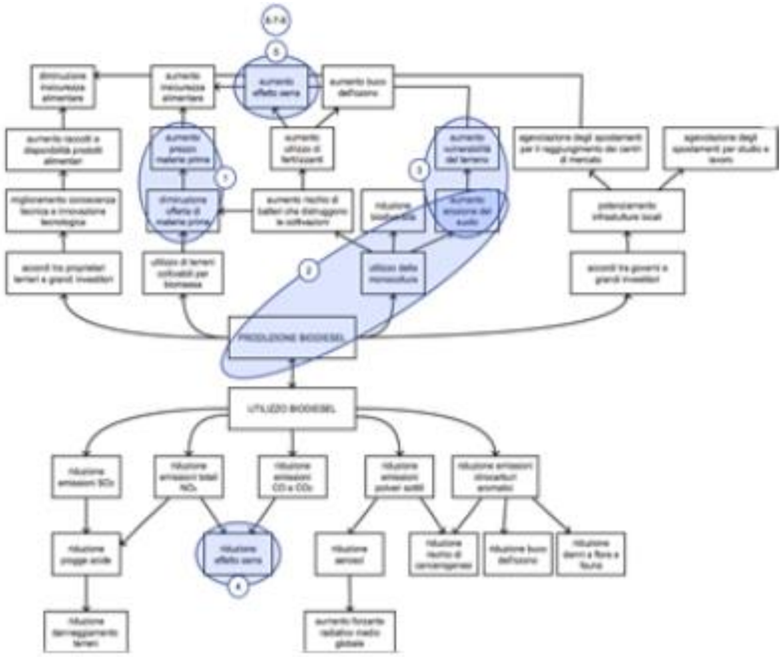


Figure 2.8. Our proposal of map where the feedback areas have been highlighted (see Annex A11 for an enlarged version).

At the end of this exercise, a final collective discussion is needed to share the work carried out by the groups. An expected issue is the difficulty in creating negative loops. In this case, the teacher can decide to encourage the students to create loops not strictly related to the map. To discuss about this difficulty and push them to find a way to overcome it are very important and to enlarge the span of possible contexts and examples within climate issues can be a way.

A final discussion of the activity is important to fix and make explicit some crucial points:

1. the biodiesel story exemplifies why climate change requires to change our ways of reasoning (from local to global and vice versa, complex systems do not admit black-and-white judgments).
2. students made experience of building and using a causal map to analyse a scientific text
3. making a decision in a complex situation implies to take into account many dimensions and the introduction of personal values

In order to focus on the previous points, the discussion can be guided by the following questions:

1. *What is a causal map? In what sense can it be used as an analytic tool?*
2. *Imagine to be the Major of your town. Would you support the use of biodiesel by introducing public incentive?*

This final discussion brings to Activity 3.

- **Possible difficulties that students and teachers can encounter.**

In this activity is possible to encounter some general difficulties and some others instead strictly related to the specific tasks.

In the first task of the activity students are asked to complete a causal map starting from the text. The activity is not usual for standard curricula and students are usually prepared in building up other kind schemas, like conceptual maps and/or summaries and/or lists. The exercise is not particularly difficult but the students may feel initially not able to carry it out and they need time to enter the logic of causal reconstruction.

In the fourth task students are asked to read the text about the production of biodiesel and compare it with the related map (already completed). The map given to the students have two crucial links highlighted and they have to explain the causal reasoning represented by the arrows. This task let to go from the map to the text and to make explicit two reasoning beyond causal chains. Even this task is not particularly usual, so teachers should clarify the task and may provide hints to enable students to start.

A general difficulty is to keep the students on the point of carrying on firstly the analysis and only secondly to introduce personal values and take a personal position with respect to the issue.

Another general difficulty is to find and/or invent negative feedback loops (Barelli, 2017). In order to help students to enter this kind of reasoning, they can also invent them in a situation outside the map.

- **Expected results (just in case we want to present examples of students' outputs)**

Students' outputs with respect to this set of activities are the group and the collective discussions as well as the completion of the work sheets.

- **Annexes and/or suggested sources**

Slides with the introduction and the flow of the tasks

Biodiesel story

Worksheets (one for each task)

Synthesis report for policy makers of IPCC

Activity 3 (C)

The third set of activities has the main goal *to develop specific future-scaffolding transversal skills*. The activity is made up of four different parts that are explained in the followings, it's named "Probable, possible and desirable futures for the Town *Irene*" (Annex ??) and is related to a problem of urban planning, inspired by a real situation proposed by a major of a small Italian city. The activities had just been used in two pilot studies, one with citizens (Albertazzi, 2017) and one with students (Barelli, 2017).

- **Needed materials**

Paper and pencils

Worksheets (1 per each student)

iPad (1 per group) for the data collection

- **Description of the specific activity enriched also by practical suggestions for the teacher (e.g. how groups should be made, what types of questions, why you ask that and where you can find resources for the answers)**

In the third activity, students are asked to think about futures reasoning on a concrete context and on decisions to make, values and goals to pursue, possible actions. Since the situation refers to a real urban problem, the activity has the potentiality to activate personal resources and values and to give the students transversal skills that can help them to organize their reasoning about future scenarios. The activity is inspired to Futures studies concepts and methods. The transversal skills that are supposed to be developed are future-scaffolding skills because the distinction between the three types of future, after a solid analysis of the present situation, is the starting point for a conscious and personal agency.

Students are asked first to read a brief text describing the situation, that is set in a small city named Irene. Irene is a small town that counts three commercial areas operating in the food sector: they are spatially arranged as shown in Figure 2.9.

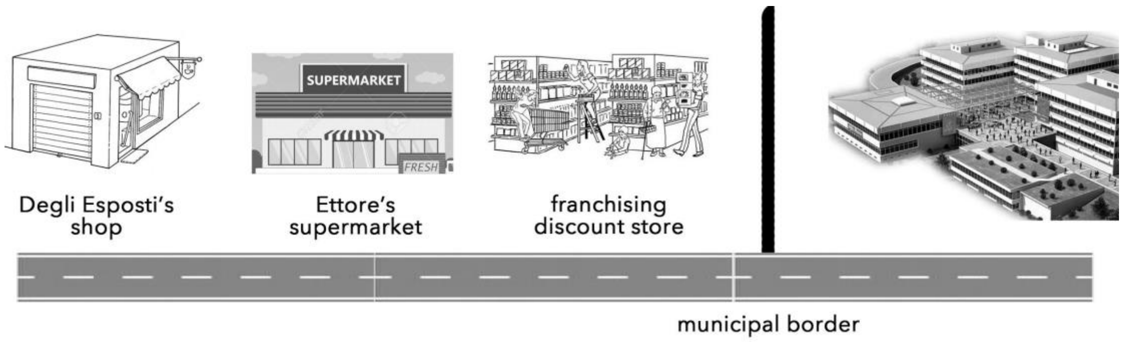


Figure 2.9. The spatial disposition of the commercial areas of the town of Irene.

The sellers are different in terms of dimension, quantity of employees, technological resources, age of the owners, kind of products and permissions to enlarge their buildings. The major of the city is asked by the owner of the most technologically advanced of them to give to him a special permission to use the space available for another owner, the older and intentioned to retire soon, who is not going to take advantage of his permission. The major has to decide if modifying or not the urban regulations approved by the Municipal Council, that would not allow any possibility of expansion.

- **How the activity runs.**

First phase: stakeholder analysis (15 minutes)

The first phase of the activity consists of the analysis of the present situation: students are asked to analyse the situation, working in groups formed by the teachers, and to outline a planning scheme of the situation acknowledging a) the stakeholders (types of people touched somehow by the decision) and b) their needs and interests.

At the end students have to share with the other groups and the teachers their analysis and to discuss briefly about it.

Second phase: exploration of future scenarios and comparison

In the second phase, teachers give the students brief written descriptions of two plausible scenarios in the view of an evolution of the town Irene from 2017 to 2030. In the first scenario, the periphery of Irene has become an attractive centre thanks to its many commercial activities that have been developed beyond the commercial area, but the historical centre has become progressively empty. The second one shows Irene as a centre of attraction for a local and diversified tourism, thanks to the gastronomic offer of shops and restaurants of the town centre and to the street market stalls regularly organized.

The students read the descriptions and teachers pose questions that they have to discuss within the group after reading:

- What values are embodied in the two scenarios? In particular, what values differentiate the two scenarios?
- Which scenario do you prefer?

To discuss the first topic, students are inspired by a list of values (given them by the teacher of projected with a PC) that typically are considered to evaluate scenarios and reasoning about their preferability in Futures Studies workshops (Annex ??).

Students resume briefly what they discussed about and if the group agreed or not deciding what scenario was the best. On the bases of this discussion, students are asked to form groups choosing their mates according to the criterion of similarity of values.

Third phase: action planning

The third phase of the activity is about the imagination of a desirable scenario for the town Irene in 2025. The scenario has to be accompanied with a catchphrase that characterizes Irene as the ideal town where to live or to visit. After this, each group of students has to plan an action that they may undertake (as singles or as a group) in the present, in order to favour the realization of the desired scenario. They are asked to describe who they are and the position they hold when realizing the action (for instance: political decision maker, private citizen, an association, society, company or firm, a bank, the headmaster of a school, *etc*.), what they intend to do and why they think this action favours the realization of the desirable scenario. In the end the group present the scenario and the actions to other students and the teachers.

Fourth phase: decision

As final part of Irene activity, the groups of students have to decide if allow extension to the owner who asked it or not, explaining why.

- **Possible difficulties that students and teachers can encounter.**

In the first phase of the activity students are asked to identify stakeholders exploring their personal knowledge of society. The activity is not scholastic and students are not prepared to reason in terms of stakeholders, so not all the students may feel initially able to carry it out. Teachers should clarify the task and the request and may provide examples to enable students to start.

In the second phase students work in groups and a possible difficulty is to understand what a value is, what is the meaning of some the suggested values. The teachers in the beginning should inspire students in order to make them, avoiding too trivial observations and to reason deeply on implications of different aspects of the scenarios on society and environment, but without influencing students too much, since the goal of this activity is to find gradually a personal position concerning choices, actions and futures. During the discussion, teachers should be able to catch and rephrase students' observations in order to help them to compose the groups.

In the third phase students have to imagine actions and their role, so the difficulty is just in terms of emotional feelings about future reflecting with other students and finding an agreement with them. Transversal skills concerning working in teams are necessary so students may have difficulties of this kind. Teachers should monitor the groups work to help students who are not comfortable with their groupmates or that are not working with the others.

In the fourth phase students may not be able to connect decision making and the rest of the activity, since the decision concerned the first phase. Also in this phase students may be tired and not very concentrated after the whole activity.

- **Expected results (just in case we want to present examples of students' outputs)**

In the first phase students produce a list of stakeholders and their possible interests that can be presented to the other.

In the second phase they produce a resume of the group discussion to present to the other groups and the teachers.

In the third phase students produce a description of the scenario and their actions, to present to the other groups and the teachers.

In the last phase, students propose a decision and a motivation, providing arguments in favour to their choice in terms of values and preferable scenarios and possible dynamics that the decision could trigger.

- **Annexes and/or suggested sources**

Description of the situation (Irene, the sellers, the decision to make)

Worksheets (tasks for every phase of the activity)

Master degree dissertations (Albertazzi, 2017; Barelli, 2017)

Report concerning futures studies that inspired the activity (Presentation by Bishop, Video of Bishop's conference)

Final remarks about part 2

TO BE ADDED!!!!!

References about part 2

Albertazzi, L. (2017). *Scientific knowledge and citizenship skills. Pilot study with adult citizens about the themes of complexity and future*, master dissertation.

Barelli, E. (2017). *Science of complex systems and future-scaffolding skills: a pilot study with secondary school students*, master dissertation.

IPCC (2014). *Climate Change: Synthesis Report*.

OECD (2016). Education at a Glance 2016: OECD Indicators. OECD Publishing, Paris. Available at: http://dx.doi.org/10.187/eag-2016-en [accessed 1 June 2017].

PISA (2015). *Draft science framework*. Available at: https://www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20Science%20Framework%20.pdf [accessed 1 June 2017].

Part 3 – Action competence and agency (Icelandic group)

Learning outcomes

At the end of part 3, students will be able to synthesize new understandings and competences from parts 1 and 2 and relate them to their personal and professional visions of the future and their role and purpose in the future(s). Specifically, they will be able to:

- Critique and revise their own future visions in light of new knowledge and perspectives gained during parts 1 and 2.
- Define, map and analyze a climate change problem of their choice and its system.
- Identity and categorize leverage points in the system.
- Describe probable, possible and desirable futures for the problem and the system.
- Articulate a strategy to achieve a desirable solution for the problem, based on its systemic context.
- Role play in groups to present the strategy and each person's relation to creating the desirable future.

Overview:

- 4-6 class hours plus 2-4 working hours which can take place outside of class or as in-class time dedicated to group work to create the presentation

- As the comprehensive project at the end of the module, this part relies on students having some preparation in climate change content and working independently. The approach builds on student interest, critical thinking and creativity as well as the ability to work together in groups.

- The VISIS methodology and the futures studies workshop methodology are both good sources to refer to in guidance for this part. This part was inspired by both and combines elements of both with original ideas in the creation of this part.

Activities (description activity per activity) (*)

Activity 1: Rewriting the future

- Needed materials: dream journals, writing tools.

- In this activity, students revisit a dream they have already written for the future and revise it in light of their learning experiences during parts 1 and 2 of the module. If students have not already written a dream for the future and/or have not done parts 1 and 2 of the module, they can still do this part by writing a dream they have for the future in which they describe themselves, their lives, their surroundings and their professional and personal roles in the world.

- Students work individually and if possible, should be given space and time to find a quiet place to reflect and collect their thoughts on their dream future.

- Teachers encourage students to dream of an ideal future. Students should not restrict themselves to dreaming of a possible or probably future; they should not let practicalities or problems hinder their vision for the most ideal future they can imagine.

- If students are revising a previous future dream, teachers can ask questions like:

  "What do you think when you read it now? Have any of your ideas started to change?"

- If this part follows parts 1 and 2, teachers can ask questions to reinforce and incorporate previous learning, for example:

  "What have you learned so far? How did you learn it? What made an impression on you? What are you interested in learning more about?"

- To guide students in writing their dream future, teachers can ask:

  "How do you see yourself in, say, 15 years? What kind of a world do you live in? How do you live? What do you do? What roles do you play in your community?"

- This may be a difficult task for some students, and teachers should observe to see if someone is struggling with writing an assignment of such a personal nature, and assist or encourage them perhaps by talking through the assignment aloud and in private.

- What to expect? See example of students' writing from the summer school, perhaps a pre-assignment and then a revision.

Activity 2: Problem mapping and systems analysis

- Needed materials: large paper and writing tools and/or computers

- The purpose of this activity is to guide students into a deeper understanding of a problem they are interested in so that they realize how it is situated in a system and interrelated to other systemic factors.

- First, students think to themselves and decide one problem they want to work with, and write it down on a little piece of paper.

  Teachers can guide students in finding a topic by saying:

  "Find one problem related to climate change that you find interesting. Think back over the topics you have learned about in this module as well as topics you have learned about before or perhaps only heard about. Remember there are many aspects to climate change, not only meteorological but also ecological, social, cultural, economic, political and others. Choose a problem that calls to you, something you want to dig more deeply into."

The teacher collects the papers and puts the students in groups based on common interests. If there are some students who do not have something in common with others, then the teacher must talk with the student and let them choose a group to join based on the topic.

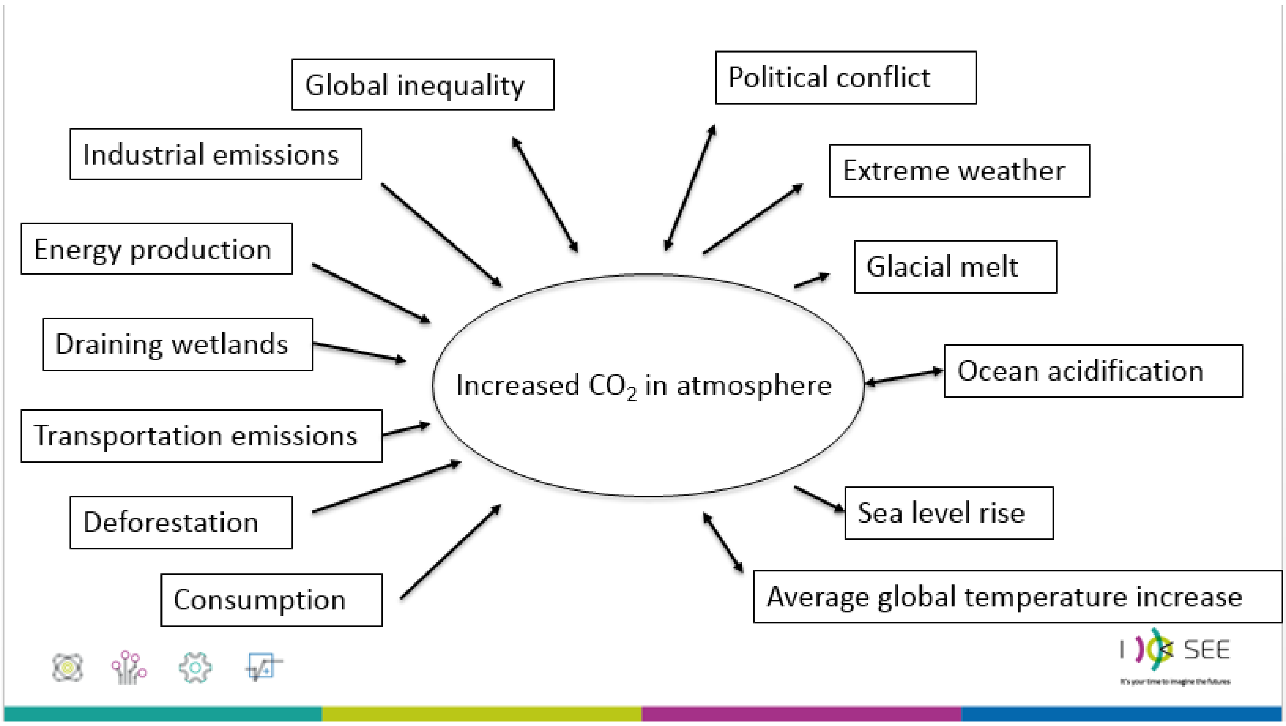
- Now in groups with one problem to focus on, students first brainstorm a definition of the problem and related factors.

  Teachers can guide students in this brainstorm by saying:

  "Write out a definition for the problem you have chosen. What exactly does it mean? Why is it a problem? What are the causes and consequences it implies? Write down anything you can think of that is related to the problem."

- Based on the brainstorm, students create a visual map of the problem and its system. The problem itself should be in the center and it is surrounded by causes, consequences and other conditions or related factors within the system. Arrows can be used to show relationships among the elements of the system with each other and the problem.

  For example:



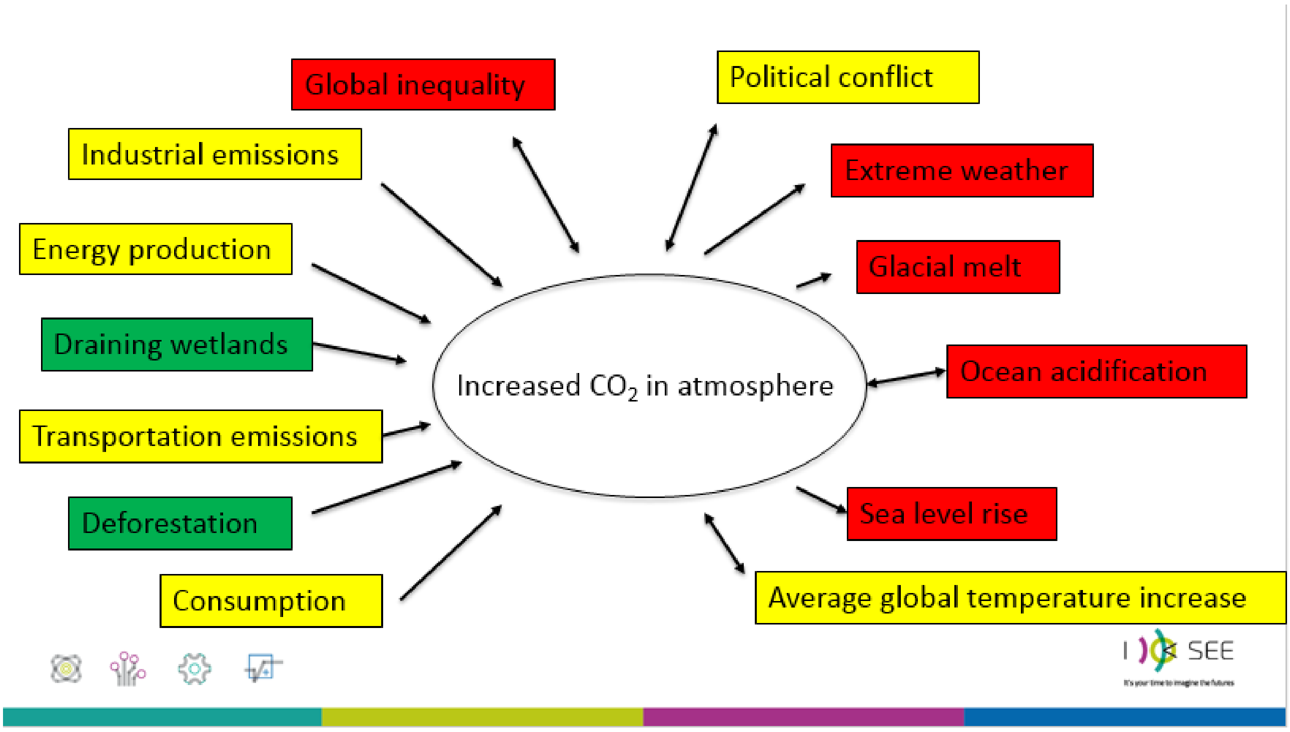
- Now groups analyze their maps in terms of how easily changed each part of the system is.

- Teachers' guidelines to students:

"Think about the different kinds of change that can be used to influence a system, for example: technology, investment, infrastructure, policies, regulations, awareness, attitudes, values. Think also about feedback cycles and how their dynamics can be influenced. Then use your judgment to categorize each part of the system as red, yellow or green. Use red to indicate aspects that are very difficult to change, yellow for aspects that would require something in order to change them, and green for aspects that can be changed easily or with the help of something that is easily acquired.

The green points are the "leverage points" in the system, or the part of the system that can be influenced and can in turn change the system."

For example:



- Now each group must choose one leverage point to focus on. This will be the part of the system for which they develop a strategy for changing the system in the next activity.

- This can be difficult for students who have not done mapping activities before, but it is important for teachers to know that there is no one "right" map of a problem. The maps do not have to be exhaustive; it is more important that students work with a problem they are interested in as this is key to building their sense of investment and ultimately empowerment.

Activity 3: Creating history

- Needed materials: paper and writing tools and/or computers

- In this activity, groups design a strategy for responding to the problem based on their system analysis from activity 2. They then present their strategy in a success story in the past tense.

- Now groups have chosen a problem, mapped it out, analyzed the parts of the system, and identified one leverage point they want to create a strategy to change. Teachers now guide the students to zoom out once again and think about the problem and its possible futures:

  "Thinking about the futures that could be for the problem you've chosen. What are the probable, possible and desirable futures for this specific aspect you want to change? Think about how futures are different when they are based on reactions or actions (discuss difference between mitigation and adaptation). Think about the different stakeholders and interests that can also influence the system. Imagine the multiple perspectives they represent, their motivations and their desires.

  Now, choose one ideal future for your problem and the leverage point you are working with, and describe it. It is the year 2032: What is the state of the problem?"

- The next step is for the groups to backcast each step of the way towards the ideal future they have now described, articulating what strategy they employed to influence the critical leverage point that changed the system and solved the problem.

  Teachers' guidance:

  "Trace back, step by step, what happened during the past 15 years to achieve the change in the system you have described. Focus on the specific leverage point you identified and the scenario for 2032 you envisioned.

  What is required to get to the 2032 you have chosen? What do you have to do? What is required of others? What material requirements do you need?

  What is your role in the change? Who do you want to be in this plan? What does your plan mean for your future personally and professionally? What obstacles did you encounter and how did you overcome them? What do you need to make this fantasy future come true?

  Keep in the back of your mind there are different approaches to influencing different aspects of systems. Imagine how influential people become who they are and continue to change themselves. Think about how you are already becoming your future self, but how you also exist within a system. How can you influence the system you live in that determines what is probable, possible and desirable for you?

  Based on the history you have written for the next 15 years, describe the strategy you will use to change the aspect of the system you can and want to change in order to address the problem you have chosen."

- Finally, each group creates a presentation of the history of the next 15 years. The year is 2032 and they are telling their success story of how they managed to solve this critical problem by using a leverage point to change the system. Each student takes on a role in the change they have chosen for themselves, and in the presentation they are in character.

  Teachers' guidance:

"Create a way to present your vision and plan to the group using any method of communication or media you like. Presentations should take 20-30 minutes. Think about how to make others understand your thinking process. Justify your choice of problem and leverage point, and explain how you analyzed the system you are working with.

Tell how the world is in 2032, and specifically what the situation is for the problem you are addressing and the aspect you are using to influence the system of the problem. Tell about who you are and what your role is in the change.

Explain what has happened over the last 15 years and how it happened. What strategy did you employ? What hindrances do you meet? What obstacles did you overcome? What failings did you experience? What were you able to accomplish and how? What did you use to be successful? Who helped? If you could do it all over again, what would you do differently?"

- It is very difficult to backcast (to think of the future in past tense), but it is essential that teachers hold students to that task. It is also difficult for some students to role play, but this is also critical so that they connect their ideal future directly to their role in creating it.

- Expected results: can include an example from the summer school.

Final remarks about part 3

The activities that make up part 3 work best when taken all together because they reinforce each other, but it is not impossible to take them individually. This part is very demanding on students' imagination but also on their critical thinking and analytical skills. It serves as a challenging and empowering comprehensive activity that can also be the module assessment task, as well as a springboard for other modules of other topics or indeed many other kinds of learning activities that build on future imaginations and systems thinking.