IO7: Aims of SSI and the curriculum

National and Kapodistrian University of Athens

IO7 Module aims

- Module O7 focuses on
  - (1) the aspects of environmental SSIs that are related to the **educational goals** of schools (as intended in the curricula)
  - (2) how future teachers can embed them in curricula (as enacted in **classroom practices**).

Structure of the module

- **I. Introducing the Environmental Socio-Scientific Issues (EnvSSIs) and understanding their connection with mathematics and science curriculum.**
  - **1.1:** Brainstorming about EnvSSIs.
  - **1.2:** Reflecting on EnvSSIs' connections with mathematics & science education.

- **II. Exploiting research findings on connecting EnvSSIs to mathematics and science educational goals.**
  - **2.1**: EnvSSI and education.
  - **2.2:** Readings on Teachers' challenges.
  - **2.3:** Example of enacting EnvSSIs in classroom: The case of role-playing scenario.
  - **2.4:** Theoretical frameworks for analysing students' arguments.

- **III. Experiencing how to enact EnvSSIs in mathematics & science classrooms.**
  - **3.1:** Dealing with the Paper or Plastic Bag issue: Role-playing scenario.
  - **3.2:** Dealing with a specific Lake Drainage and re-creation issue: Multiplicity of the factors & "Uncertainty".

- **IV. Implementing an EnvSSI-based mathematics and science lesson and connecting it to the national curriculum.**
  - **4.1:** Lesson design.
  - **4.2:** Reflecting on the lesson designs.

I. Introducing the environmental socio-scientific issues (EnvSSIs) and understanding their connection with mathematics and science curriculum.

Activity 1.1: Brainstorming about EnvSSIs

Which are better for the environment, paper or plastic bags?

Is global warming caused by human activity or by natural cyclical phenomena?

- Reflect on these questions. Share your opinions by arguing them.
- Is there a unanimous answer/ a common output? Are you certain about your viewpoint?
- What do you think you need to defend your claims & to convince opponents of your opinion?
- How can science and mathematics help you in answering these issues?

Activity 1.2: Reflecting on EnvSSIs' connections with mathematics & science education

- Provide examples of EnvSSIs.
- What characteristics do you identify in such issues?
- Do you think that it is important to teach such issues in the school? Why?
- Are such controversies included in your mathematics & science national curriculum? If so, how?
- Which role can EnvSSIs play in achieving expected learning outcomes of the mathematics and science curriculum?
- What would be your concerns if you were asked to teach these issues?

II. Exploiting research findings on connecting EnvSSIs to mathematics and science educational goals

Activity 2.1: EnvSSIs and education (1/2)

- The Socio Scientific Issue movement has drawn from a wide swath of interrelated scholarship, e.g.
  - epistemological maturation,
  - socio-moral discourse,
  - emotive reasoning,
  - character education,
  - nature of science and argumentation,

- that uniquely positions it as a sociocultural progressive framework serving as a counterpoint (or a complement) to recent STEM initiatives as commonly conceived and practiced in academia (Zeidler et al, 2019).

EnvSSIs and education (2/2)

- *'Environmental education typically emphasises private share environmentalism… i.e., what an individual can do to reduce negative effects on the environment. However, effective actions when dealing with environmental problems are collective…, therefore, students should be given opportunities to discuss the societal and global sphere and analyse environmental problems as public issues'* (Sternäng & Lundholm, 2012).

- EnvSSIs are controversial issues that have a basis in science and mathematics and require people to engage in discussion and debate. In the decision-making processes, they require the use of evidence-based reasoning, as well as a degree of moral reasoning or the evaluation of ethical concerns.

Task: After reading the above extracts, discuss in groups how this type of issues could be related to the national curriculum.

Activity 2.2: Readings on Teachers' challenges

- Read the following extracts from research literature indicating challenges and dilemmas that teachers experience when integrating EnvSSIs into mathematics or science teaching

  - ***Teachers' value-free beliefs.*** *Many teachers believe that science and mathematics should be objective and value-free, (Bryce & Gray, 2004), and it is not the role of science and mathematics education to attempt to solve social, political issues. Also they feel insecure when trying to not promote their personal views about the issues involved (Gayford, 2002).*
  - ***Teachers' ill-preparedness in teaching EnvSSIs.*** *Many teachers feel ill-prepared to select relevant socio-scientific topics and to teach them (Bryce & Gray, 2004) and to deal with the uncertainty of the students' solutions and ideas (Evagorou, 2011).*
  - ***Classroom management in leading debates.*** *Many teachers express difficulties in leading debates or controversial discussions, judging the non-scientific aspects of the issues involved. Thus, they feel insecure in handling conflicting aims in terms of enhancing the students' independence as learners (in a student-centred approach) while trying at the same time to control the learning outcomes (by acquiring basic science knowledge) (Aikenhead, 2006; Bosser et al., 2015).*

Task: What issues do you recognize in mathematics and science curriculum objectives and their enactment in the classroom?

Activity 2.3: Example of enacting EnvSSIs in classroom: The case of role-playing scenario.

- **Task 1:** The following table provides an analysis of enacting EnvSSIs in terms of the school subject, the resources used, the content knowledge and curriculum aims and the design of a role-playing scenario.

School subject	Resources	Curricular aims	Role-playing scenarios
Science	e.g., Magazine articles, YouTube videos, scientific presentations/reports, graphical data	e.g., greenhouse effect, climate change, recycling	e.g., a school decision not to offer meat dishes in the school restaurant
Mathematics		Modelling, problem solving, argumentation	

- Try to make sense of this table through the examples provided in the table.

(Belova, Eilks, & Feierabend, 2015; Höttecke et al. 2010)

- **Task 2:** Read the role-playing scenario on “Green mobility” provided below.

Green Mobility

As **experts for Green Mobility** you stand for alternative means of transportation like electric cars, alternative fuels such as biodiesel, and public transport with buses and trains. **Your goal is the reduction of greenhouse gases and climate protection** with the help of alternative means of transportation and the limitation of individual transport. Individual transport means that everyone uses his own car or motorcycle. Therefore **a law** on the increase of the minimum age for a driving license up to 21 years is **a good idea** to achieve goals, as it forces young people to use public transport and limits the overall traffic.

- Specify the school subject and the mathematical and scientific ideas involved.
- Design your own role-playing scenario related to an EnvSSI from your choice and complete correspondingly the table provided above.

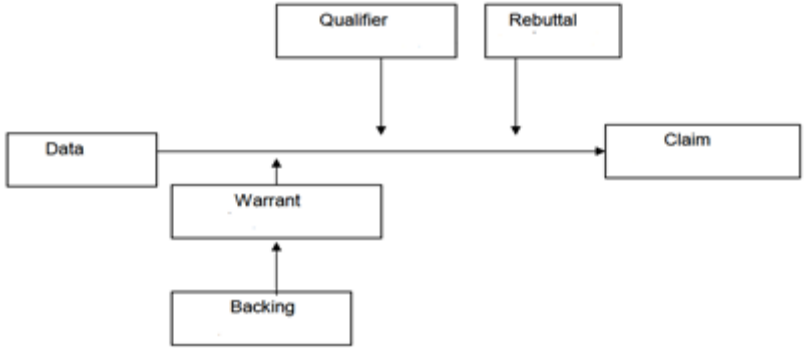
Activity 2.4: Theoretical frameworks for analysing students' arguments

In the following, we will present two theoretical frameworks:

- Toulmin's framework
- Belova et al.'s framework

Toulmin's framework

The *construction of single arguments* is based on Toulmin's framework with the following elements: the *claim*, the *data,* the *warrant*, the *backing,* the *qualifier* and the *rebuttal.* The first four elements determine the soundness of the arguments while the last two their strength.



- *Claims* are statements that advance the position being argued for.
- *Data* are the foundation or supporting evidence on which the arguments is based.
- *Warrants* are the logical connections (a general rule of inference) between data and claims that indicate how a claim is supported by the data.
- *Backing* supports the validity/legitimacy of the warrants.
- *Qualifiers* refer to the degree of strength and certainty in one's argument while *rebuttals* consist of exceptions to the applicability of the warrant

Belova, et al.'s (2015) framework

- **Domain:** Where do the arguments used by the students come from (science/everyday life/society/politics)?
- **Level of argument:** How complex are the arguments?
- **Reference:** Do the students make references to each others' statements? Does a conversation arise?

Task: analyzing students' arguments

Below is a classroom task on the basis of Hydrogen fuel bus (Dawson & Carson, 2020)

> *"Between 2004 and 2007, Transperth trialled three EcoBuses in Perth which ran on hydrogen fuel cells as their fuel source. The benefit of using a hydrogen fuel cell is that the only waste emissions produced are water and heat. At the conclusion of the trial, the three buses had travelled 258,000 km and carried over 320,000 passengers. Three hundred tCO2eq (tonne of CO2 equivalent) were saved by not using regular diesel buses. Although the trial was deemed a success by Transperth, the WA government has decided not to proceed any further with the EcoBuses, claiming the cost to maintain each bus was too high a price to pay compared to a regular bus.*
> ***Do you think the WA government made the right decision?"***

- **You find below an example of analysis of a student's response according to Toulmin's framework**

CLAIM: Yes. "I think the WA government made the right decision (claim) as the buses would cost a lot of money and would put our state to bankrupt (data) meaning we will have to cut down on other expenses and Centrelink payments for those who are struggling (backing) just so we can have ecofriendly public transport. Also not many people use buses as many own cars (data) which means it is not really helping the environment. The difference it will make is not very big."

- **Analyse the following student's response utilizing both Toulmin's and Belova et al.'s frameworks**

CLAIM: No. "The reason for this is because as the statistics showed, 300tCO2eq were saved by using these types of buses, which indicate that a great amount of tCO2eq had been prevented from entering the atmosphere and causing further damage. Furthermore, it is also stated that the only waste emissions produced are water and heat; therefore, less harmful greenhouse gases are produced. If less greenhouse gases are produced, this means that the damage to the natural balance of producing greenhouse gases is slowed down(data),which means that by using this Ecobuses, it will be worth it for the long run as this will be beneficial for the environment. Therefore, the cost would not matter to the WA government because paying for the Ecobuses is like paying for a better future as less damage will be done to the environment."

III. Experiencing how to enact EnvSSIs in mathematics and science classrooms

Activity 3.1: Dealing with the Paper or Plastic Bag issue: Role-playing scenario

1) Below, you can find an extract of the Washington Post Company newspaper (2007) that compares the paper and the plastic bag.

washingtonpost.com > Arts & Living

MORE THAN MEETS THE EYE

An occasional feature that digs deeper into things you've been wondering about

Paper or Plastic?

We hear the question almost every time we go grocery shopping. Some shoppers answer automatically: plastic — convinced that they are making a better choice for the environment. Others ask for paper, believing the very same thing. The reality is that both paper and plastic bags gobble up natural resources and cause significant pollution. When you weigh all the costs to the environment, **you might just choose to reuse:**

PAPER

PLASTIC

CONSUMPTION

Americans consume more than **10 billion paper bags** each year. Some **14 million trees** are cut down annually for paper bag production.

Four out of five grocery bags in this country are plastic. The U.S. uses 100 billion plastic bags annually, made from an estimated 12 million barrels of oil.

Worldwide, an estimated 4 billion plastic bags end up as litter each year. Tied end to end, **the bags could circle the Earth 63 times.**

PRODUCTION

Paper, of course, comes from trees. Trees are grown or found, then marked and felled.

1. Logs are moved from the forest to a mill, where there is a three-year wait for the logs to dry before they can be used.

2. Logs are stripped of bark and chipped into one-inch squares. The chips are "cooked" with tremendous heat and pressure.

3. Then, they are "digested" with limestone and sulfurous acid until the wood becomes pulp.

4. The pulp is washed, requiring thousands of gallons of fresh water and bleach, then pressed into finished paper.

5. Cutting, printing, packaging and shipping to make paper bags require additional time, labor and energy.

It takes more than four times as much energy to manufacture a paper bag as it does a plastic bag.

Energy to produce bags:

Plastic — **594 BTUs***

Paper — **2,511 BTUs**

7 in 10 Americans do not know that plastic is made from petroleum products, primarily oil, according to a recent nationwide online survey.

* BTU = British thermal unit

Plastic is a by-product of oil refining. Plastic bags are made from polyethylene, which comes from oil refineries as small resin pellets.

1. A machine heats the pellet to about 340 degrees and pulls out from it a long, thin tube of cooling plastic.

2. A hot bar is dropped on the tube at intervals, melting a line.

3. Each melted line becomes the bottom of one bag and the top of another.

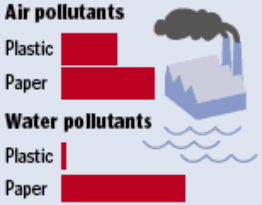
4. The sections are cut out and a hole for the bag's handles is stamped in each piece.

PAPER

POLLUTION

The use of toxic chemicals during the production of paper for bags contributes to air pollution, such as acid rain, and water pollution.

The production of paper bags generates 70 percent more air and 50 times more water pollutants than production of plastic bags.



Plastics production requires toxic chemicals. In an EPA ranking of chemicals that generate the most hazardous waste, five of the top six were commonly used by the plastics industry.

Hundreds of thousands of marine mammals die every year after eating discarded plastic bags. Turtles think the bags are jellyfish, their primary food source. Bags choke animals or block their intestines.

RECYCLING

Paper must be returned to pulp by using many chemicals to bleach and disperse the fibers. Although paper bags have a higher recycling rate than plastic, each new paper grocery bag you use is made from mostly virgin pulp for better strength and elasticity. Bags that are recycled are often turned into corrugated cardboard, not new paper bags.

It takes 98% less energy to recycle a pound of plastic than it takes to recycle a pound of paper.

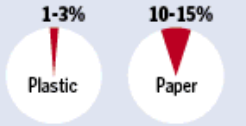
Energy used to recycle bags:

Plastic | 17 BTUs

Paper 1,444 BTUs

But recycling rates of both types of bags are extremely low.

Percentage of bags recycled:



Recycling almost any kind of plastic involves remelting and re-forming it. Because bags must first be separated by the type of plastic they were made from, the process is time-consuming and expensive. For example, it can cost $4,000 to process and recycle 1 ton of plastic bags. This can then be sold on the commodities market for about $32. More often than not, bags collected for recycling never get recycled. A growing trend is to ship them to countries such as India and China, where they are cheaply incinerated under more lax environmental laws.

PLASTIC

BIODEGRADABLE?

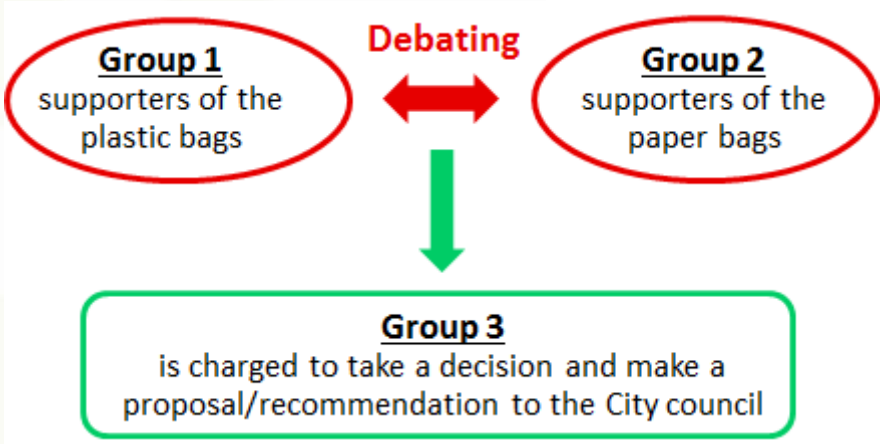
Paper is degradable, but it cannot completely break down in modern landfills because of the lack of water, light, oxygen and other necessary elements. About 95 percent of garbage is buried beneath layers of soil that make it difficult for air and sunlight to reach it.

Even though petroleum-based plastic will never biodegrade, nearly **4 in 10 believe plastic will biodegrade** underground, in landfills or in the ocean.

Petroleum-based plastics are not biodegradable, meaning they will not decompose over time. But they do take up less space than paper in a landfill: 2,000 plastic bags weigh 30 pounds; 2,000 paper bags weigh 280 pounds.

Task 1: Debating through a role-playing scenario.

Based on the issue: *Are plastic bags or paper bags better for the environment?* described in the above extract, form three groups and perform a role-playing scenario as following:



- Group 1 and Group 2 will prepare an argumentation to support their views to form a debate in front of Group 3.
- Group 3 will write a report to recommend to the city council of your city about the use of plastic or paper bags. Are the evidence-based arguments provided strong enough to persuade the city council?

To prepare this task (debate & recommendation), you can

- search in your national curricula for tasks, information or resources about this issue,
- use resources or data from your everyday life,
- carry out your own internet research or/and use the references given below:
  - the Environment Agency's report: "Life cycle assessment of supermarket carrier bags: a review of the bags available in 2006".
  - the report "Life Cycle Assessment of Reusable and Single-use Plastic Bags in California", J. Greene, 2011.
  - the NGO UNEP report "Single-use plastics, a roadmap for sustainability", 2018.

Activity 3.2: Dealing with a specific lake Drainage and re-creation issue: Multiplicity of the factors & "Uncertainty".

The story of Karla Lake in Thessaly, Greece

Karla lake is located in the central part of Greece. It had a rich biodiversity.

It was drained in the early 1960s and then re-flooded in recent years.

- Below you can find
  - Some reasons that were advanced for the decision for drainage.
  - Some consequences that were observed after the drainage.
  - Some reasons for the decision for re-creation.

- Reasons for the **decision to drain**:
  - The fluctuations in the water levels
  - The floods in the area
  - The need to create more farmland
  - The reduced catches
  - The need to reduce malaria epidemics
- Environmental and social **effects of the drainage**:
  - Rapid fall of groundwater
  - Pollution in the closed gulf and appearance of phytoplankton
  - Appearance of deep cracks and destruction of buildings
  - Destruction of the fauna and flora of the area
  - Adverse changes in the microclimate of the region and increase of extreme weather phenomena
  - Inability to supply water for cities and villages
- The **decision for re-creation**.
  - It was found that the effects on the ecosystem of the area were greater than the benefits offered by its drainage. Thus, the re-creation of the lake was decided.
  - Today, efforts are being made to carry out the recreation, which started in December 2010.

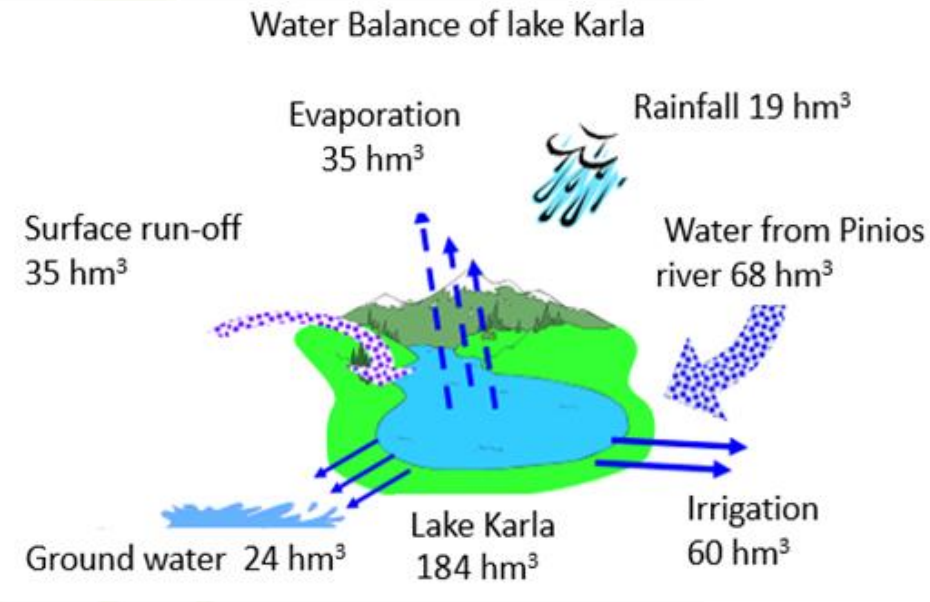
Task 1: Dealing with issues involved in lake drainage and recreation



- Based on the resources provided below or other resources of your own,
  - Reflect on the advantages and disadvantages involved in two core decisions related to the drainage and restoration of Karla Lake.
  - Identify aspects of mathematics and science teaching that you recognize in lake drainage and recreation.
  - Discuss your ideas with your peers.

Resource 1 – Yearly water balance of Karla Lake

- The figure below shows the yearly average values of some key functional characteristics of Karla Lake.



Source: Kagkalou, Υ.ΠΕ.ΘΕ. | Υδάτινοι Πόροι και Περιβάλλον Θεσσαλίας.
https://www.ypethe.gr/sites/default/files/basicpagefiles/2008_11_ypehode_stoiheia_ergoy_karlas.pdf

Resource 2 – Water Quality & Environmental Condition of Karla Lake

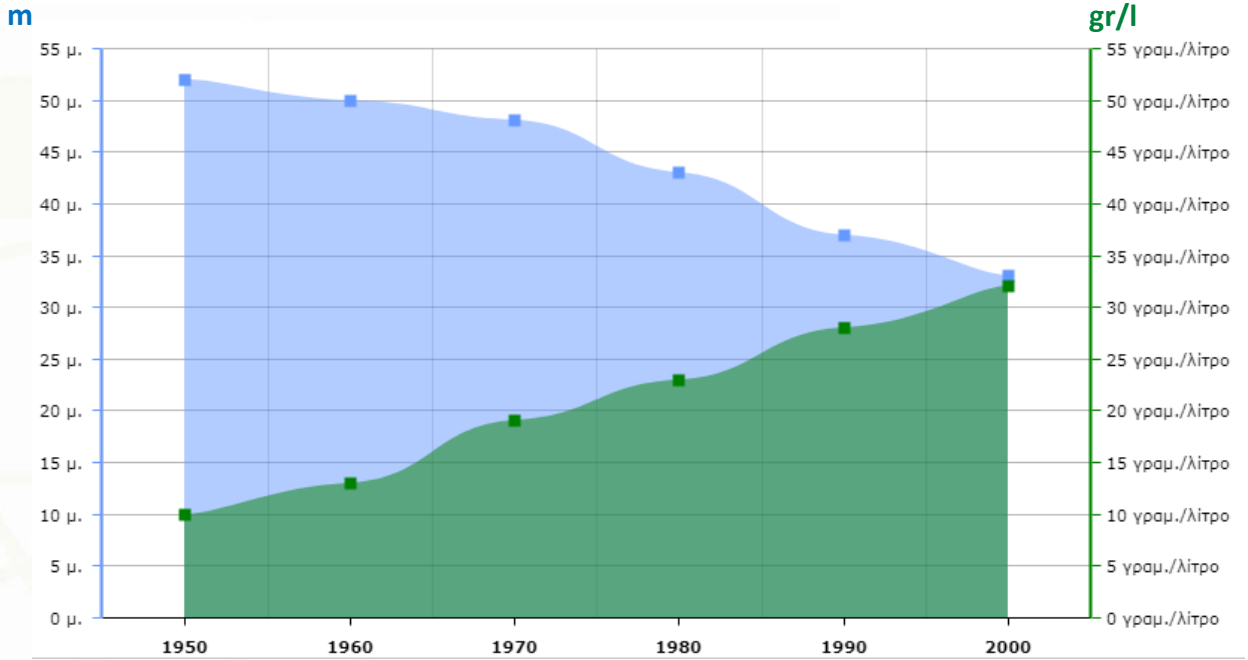
- The table below compares some measurements made in 2017 at the Karla's reservoir with respect to limits set in Directive 2006/44 / EC for the welfare of the fish Cyprinidae.

Parameters	Limits set in Directive 2006/44 / EC	Winter 2017	Spring 2017	Summer 2017	Average
pH	6-9	7,82	8,9	8,65	8,46
Total suspended solids (T.S.S.)	≤ 25 mg/lt	18	224	232	158
Biochemical oxygen demand (B.O.D5)	≤ 6 mg/lt	6,05	13	26	15,02
Nitrites (NO_2^-)	≤ 0,03 mg/lt		0,16	0,18	0,17
Ammonium (NH_4^+)	≤ 0,2 mg/lt		1,4	1,88	1,64

Source: Kagkalou, Υ.ΠΕ.ΘΕ. | Υδάτινοι Πόροι και Περιβάλλον Θεσσαλίας.
https://www.ypethe.gr/sites/default/files/basicpagefiles/2008_11_ypehode_stoiheia_ergoy_karlas.pdf

Resource 3 – An example of the salinity evolution of a lake

- The graph below shows the relation between the water level and the salinity of a lake.



Source: http://photodentro.edu.gr/lor/r/8521/10918 from the site Photodentro: a Greek National Aggregator of Educational Content developed by the Greek Ministry of Education.

Task 2: Discussing about "uncertainty"

- Read the following extract from Barwell (2013)

In post-normal science, **values and facts cannot be separated, in part due to the problem of uncertainty.** Climate models, for example, include uncertainty and any possible action to **deal with climate change will have uncertain effects** to a greater or lesser extent. Deciding which information to use, which voices to hear and which methods to try, depends as much **on values as it does on scientific facts**.

- Discuss in your group how the "uncertainty" involved in the Karla Lake issue could be dealt in a classroom lesson?

IV. Implementing an EnvSSI-based maths and sciences lessons and connecting it to the national curriculum.

Activity 4.1: Lesson design.

- Task 1: Select an EnvSSI and reflect on this issue
  - Describe aspects of the issue (e.g., controversy, uncertainty, national or international topic, what are the social and scientific implications related to this issue)
  - Identify connections with the national curriculum, to what extent the issue is addressed in the school subjects.

Task 2 (Homework) : Design a mathematics or science lesson dealing with the EnvSSI that you have selected.

Take into account the following criteria used for assessing the lesson designs

- Is the lesson clearly connected to the maths or science school curriculum:
  - To what extent is the lesson design connected with specific maths and science school curriculum objectives.
  - To what extent is the mathematical and/or scientific content knowledge of the EnvSSI addressed in the lesson.
- To what extent are the uncertainty and the controversy of the issue dealt with in the lesson design:
  - Does the lesson design involve a debate?
  - Is there an evaluation of peer's claims and arguments?
  - Does it involve a scenario (e.g. a role playing, writing a report…)
  - Is it required from pupils to make a conclusion?

Activity 4.2: Reflecting on the lesson designs

- Present your lesson design.
- Reflect on the following:
  - What type of mathematical or scientific knowledge is involved when teaching specific EnvSSIs?
  - What themes about connections of EnvSSIs and the curriculum are raised?
  - How is the uncertainty of the EnvSSI you have designed dealt with?
  - What difficulties have you encountered when designing the lesson (i.e. the choice of an EnvSSI, pre-requisite knowledge, connection with the curriculum, etc.)

References

- Barwell, R. (2013). The mathematical formatting of climate change: critical mathematics education and post-normal science. *Research in Mathematics Education*, *15*(1), 1-16.
- Belova, N., Eilks, I., & Feierabend, T. (2015). The evaluation of role-playing in the context of teaching climate change. *International Journal of Science and Mathematics Education*, *13*(1), 165-190.
- *Dawson, V., Carson, K. (2020). Introducing Argumentation About Climate Change Socioscientific Issues in a Disadvantaged School. Res Sci Educ* ***50,*** *863–88.*
- Höttecke, D., Hössle, C., Eilks, I., Menthe, J., Mrochen, M., Oelgeklaus, H., & Feierabend, T. (2010). Judgment and decision-making about socio-scientific issues: A fundament for a cross-faculty approach towards learning about climate change. In I. Eilks & B. Ralle (eds.), *Contemporary science education* (pp. 179-192), Aachen: Shaker.
- Toulmin, S. E. (1969). The uses of argument. Cambridge, UK: Cambridge University Press.