



# COOPERATIVE PROBLEM SOLVING THROUGH NATURAL DESIGN

How does nature ensure sustainability?  
How does nature make use of the talents of its members?



Erasmus+



## AGE RANGE

12–16



## DURATION

Preparation:

10 min.

Activity:

95 min. / 2 lessons

## SUMMARY

This module explores the topic of sustainable growth and cooperation, looking for analogies of how nature copes with similar issues. The lessons are based on the “hero’s journey” learning model, during which students are faced with a problem (obstacle) and experience how to overcome it.

## BIOMIMICRY PRINCIPLES



3 – Nature fits form to function

5 – Nature rewards cooperation

6 – Nature banks on diversity



## SUBJECT(S)

- Science – *Biology, Physics*
- Design, Engineering and Technology

## LEARNING OBJECTIVES

- Students can make observations about their own and others abilities to work in a team.
- Students develop their skills to work in a team effectively.
- Students are able to apply analogical thinking.

## LEARNING OUTCOMES

- Students use analogical thinking to compare human and natural systems.
- Students apply critical thinking to a given challenge and reflect on their results.
- Students use deliberative decision making.
- Students experience and reflect on their skills in team-building.



## KEYWORDS

Observation skills;  
analogical thinking;  
discussion sharing experience;  
critical thinking;  
problem-oriented decision making

How does nature ensure sustainability?  
How does nature make use of the talents of its members?

## BIOLEARN COMPETENCES

- Students are able to identify functional design in Nature, develop greater awareness and appreciation for design excellence in Nature, and appreciate how nature works as a system which is elegant and deeply interconnected.
- Students are able to use analogical creativity to innovate, using biological models to inspire solutions to design challenges.
- Students are able to work in groups.

## SUMMARY OF THE ACTIVITIES

Activity Name	Description	Method	Duration	Location	
<b>LESSON 1. The principle of sustainability – Marshmallow challenge</b>					
1	Building tower	Students build a shock-resistant tower	• Hands-on activity	20	Indoor
2	Presentation and discussion	Presentation about sustainability and resilience; student discussion	• Teacher presentation • Discussion	25	Indoor
<b>LESSON 2. The advantage of symbiosis</b>					
3	Egg drop exercise	Students build a drop mechanism to prevent an egg from breaking	• Hands-on activity	20	Indoor/ outdoor
4	Reflection I.	Students reflect about their experiences	• Discussion	10	Indoor/ outdoor
5	Presentation	Presentation about cooperation in nature	• Teacher presentation	10	Indoor/ outdoor
6	Reflection II.	Discussion about cooperation	• Discussion	10	Indoor/ outdoor

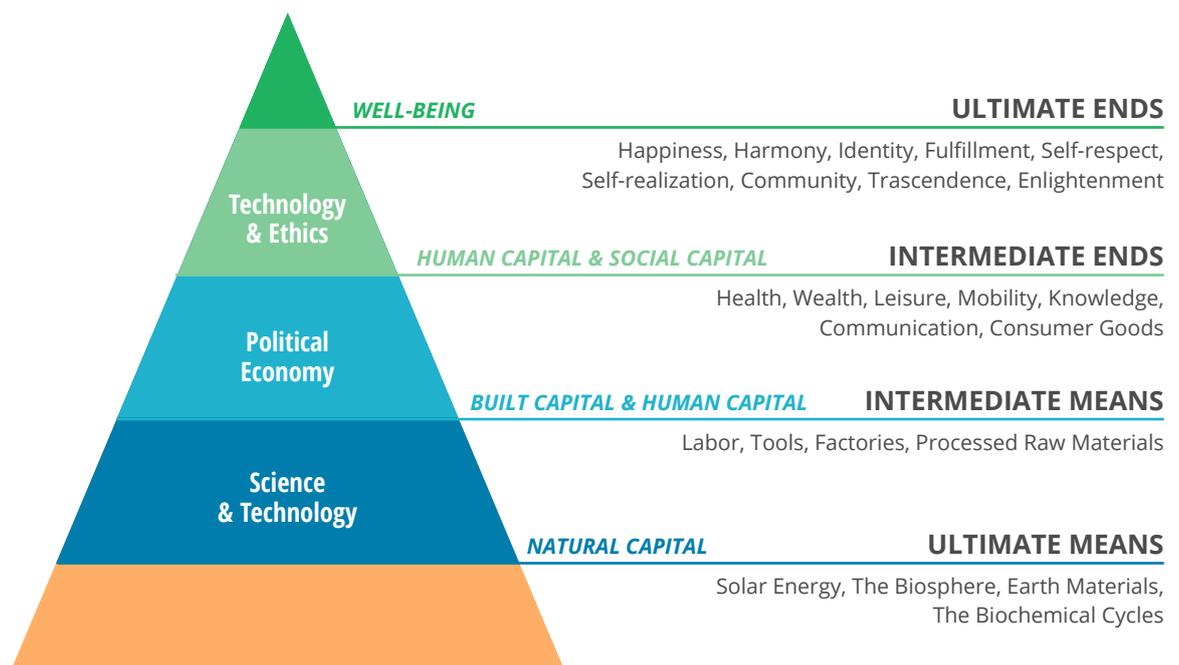
## BACKGROUND FOR TEACHERS

### Lesson 1: The principle of sustainability – Marshmallow challenge

Sustainable growth is a major topic of discussion for politicians and scientists for over 50 years. Humanity is struggling with the question of how to design economies, which can last forever. If humanity looks only for growth in population, wealth and material possessions it will, using current manufacturing and production systems, run out of resources.

The aim of this lesson is to demonstrate the economy by comparing it to a model of a tower. A tall, stable tower is possible only when it has a broad base. Every society needs natural resources to thrive, they form the foundation of every economy. In the context of our society, nature is what constitutes the foundation of our well-being (see Figure 1). This lesson tries to convey the idea of the relationship between performance (height) and security (foundation) and stresses that one cannot exist without the other. Imagine a tower with a wide top and narrow foundations – such tower would represent a society which consumes more than it can afford. Such society can exist if conditions are stable, but if a small disturbance arrives, such tower can fall down very easily. This is what the students should realize, that strong foundations of nature (healthy, vigorous, abundant) are a necessary pre-condition for a happy life.

FIGURE 1. *The triangular model of sustainable development, proposed by Herman Daly (Goodland, 1995).*



## OUTLINE OF THE MODULE

Natural resources, ecosystems and biodiversity constitute the basis of the whole structure of the society (can be thought of as nature). They are the prerequisite for all higher levels of the model, and they also ensure the resistance of the structure to disturbances. The top of the pyramid is well-being meaning that healthy a biosphere (means) is essential for our quality of life (ends).

**Lesson 2: The advantage of symbiosis**

This lesson points to the importance of cooperation in society and demonstrates how problems can be solved by collaboration utilizing the skills of the group. It introduces an exercise which aims to help students realize their strengths and weaknesses, and teach them how to form teams and deal with problems in a cooperative manner.

The lesson is about teamwork and there are a plenty of examples of teamwork in nature. Among the strongest evidence of cooperation in nature is symbiosis. Symbiosis means co-living. In biology, such relationship between two organisms is called mutualism, meaning that both partners have mutual benefit from living together. Such partnerships always comprise a trade, where both partners provide a service to and complement each other. A plant absorbs solar energy and stores it in organic compounds, while a soil fungus provides to the plant mineral nutrients in exchange for energy.

The goal of the lesson is to show that everyone has special talents and these can be complemented by joining forces with someone having complementary skills. For instance, someone is a good leader while the other is a good planner, great inventor etc. Young graduates, entering the labour market, are often required to deal with problems by forming teams which can balance and off-set their strengths and weaknesses.

ACTIVITY DETAILS

## LESSON 1. The principle of sustainability – Marshmallow challenge



**LOCATION**  
Indoor

### 1 | BUILDING TOWER

» CREATE 



**TOOLS AND MATERIALS**

- dry (not cooked) spaghetti
  - marshmallows
  - meter ruler
- mat for the shaking test



**PREPARATIONS**

Indoor: ensure tables are free of materials providing space for students to build their towers.



**RESOURCES**

Goodland, R. (1995). The Concept of Environmental Sustainability. *Annual Review of Ecology and Systematics*, 26(1), 1–24. doi:10.1146/an-nurev.es.26.110195.000245

*Tools and materials:*

- Dry (not cooked) spaghetti ► *One packet of spaghetti per group.*
- Marshmallows ► *A typical tower can use 10–20 marshmallows, therefore a 300 g bag per group should be enough for the tower and a sweet reward too. ► Blutac is also feasible, such that can be bought in an ordinary paper shop. One package is enough (Blutac contains 65 pieces).*
- Meter ruler ► *At least 1 m long as the towers can be quite tall, but preferably longer.*
- Mat for the shaking test ► *A2 or A1 paper sheets are the best possible choice. Also, cardboard or wooden mats are feasible.*

*Description:*

- *(Optional)* Participants draw numbers from a hat representing the group to which they will associate (ideally pairs). Individual work is not desirable, but it is also possible.
- The task is to build the tallest tower on the desk from the available materials. “You have 15 min to build the tallest tower, but at the same time, it should survive an earthquake. The group with the tallest tower which can withstand a mat-shake wins.”
- The teacher performs the resilience test (5 min): grab the paper mat and pull back and forth three times. The distance which the mat should travel is about 10 cm. It should take about 5 min to test all the towers: the most durable designs win and the contest is over.
  - Successful strategies should be introduced by their designer – the teacher asks the group about their strategy: “Please, explain to the class how you approached the problem. What construction design did you choose and why.”
- *(Optional)* Winning towers can be tested several times, e.g. students from other ‘competing’ groups can try to drop the tower (they will try harder), but this is off the record so the rules can be loose.

ACTIVITY DETAILS



**LOCATION**

Indoor

2 | PRESENTATION AND DISCUSSION

» DISCOVER 



**TOOLS AND MATERIALS**

- projector, PC
- [Principle of sustainability.ppt](#)



**PREPARATIONS**

Arrange the classroom for presentation.

A brief presentation follows the exercise to expand on the idea of sustainability and resistance.

- The triangular model of sustainable growth, proposed by the economist Herman Daly (Goodland, 1995), remarkably resembles the optimal marshmallow tower. Broad base means more stability and resilience to shock, and has to be in proportion to the height of the tower. Sustainable growth means investing not only in production (height), but also in security against unexpected events – disturbances – such as an earthquake (base breadth). Resistance to disturbance is what nature excels at, which is why ecosystems (e.g. a ‘jungle’ or a coral reef) adapt and sustain over thousands of years.
- The principal strategy to achieving resistance to disturbance is diversity of strategies. Much like the need to broaden the base of the tower, also sustainable systems have a broad spectrum of strategies which protect the whole against unexpected new disturbance. Diversity can mean diversity of species or genes, professions, crop types, product types, etc. For example, it is advantageous to grow a diversity of crop types. A rich community is less vulnerable to a certain pest species. In a case of a pest outbreak, it damages a certain crop type and the farmer loses only a part of the harvest instead of a whole. In forests bark beetles attack spruce trees. If we had species rich forests of mixed conifers and broadleaved trees, the loses would be much less harmful. A species community with a rich pool of genes is much more resistant and adaptive to changing conditions. In such a community there will be individuals that will be able to adapt well to changing living conditions. A species that is adapted to a certain type of habitat or climate will always struggle in case of changing living conditions than a species that is able to adapt to various conditions. In business it is always better to have a variety of products than to specialize on a single one as the demand for products can change quickly. In the job market it is better to have a variety of skills so we have a better chance to find the job we want.

ACTIVITY DETAILS

» QUESTION 

A series of questions could be asked in a follow-up discussion. Try to explore questions related to the topic of sustainable development and resistance to unexpected changes. Ask students to *visualize* a situation or topic (e.g. good life, the process of food production, the forests have all disappeared) and let them think of some potential consequences (for people in general, but also for the student personally, as that always raises interest). Try to make them realize the importance of biodiversity to human society, but avoid portraying nature as provider of services. The point is to make the students understand, that our happiness depends on nature, thus we should keep it healthy and vigorous to ensure our own well-being.

The number of possible topics or questions are immense and we propose several points with different levels of requirements for critical thinking:

1. (12–13 age group) Is nature important for people and why? Could we live without it (animals, plants, etc.) and what would be different if they disappeared? Where do you think our food comes from and what roles do the organisms and plants play?
2. (14–15 age group) Does 'wealth' mean a lot of money, friends or food? How are these related? Will I think of having friends if I am hungry? Will money have value if there is no food to be bought in the first place? What are the basics of human well-being? What role does nature play in all this, are the animals part of wealth production and how? Is it a good idea to exploit nature – to harvest all the wood and all the fields and turn it into money? What should be protected and how much of it? Are there ways to avoid the conflict between people, the economy, and loss of nature?
3. (15–16 age group) Is it better to specialize in one profession or learn more skills? Is it better to grow one type of crops or several? What happens if there is a drought event or a pest which eats specific fruit or crop? Is it better to have just one species of tree in a forest or several? Why? What could go wrong if I grow just one? Think about the role of diversity in nature and compare it to examples of diversity in society (e.g. cultural, genetic, skills and talents)? Can we also find diversity related mechanisms which ensure resistance to changes? Can too much diversity be harmful?

ACTIVITY DETAILS

LESSON 2. The advantage of symbiosis



LOCATION

Indoor / Outdoor

3 | EGG DROP EXERCISE

» CREATE 



TOOLS AND MATERIALS

- plastic bag
- piece of aluminium foil
- cotton wool
- paper
- wooden skewers
- string, a thin wire or a thread
- a plastic cup
- the rest is provided to each group (free of charge): scissors, eggs, a pricelist

Tools and materials:

- Plastic bag ▶ 1 piece per group ▶ 60 CREDITS (only one can be purchased)
- Piece of aluminium foil ▶ 1 A4 size piece per group ▶ 40 CREDITS
- Cotton wool ▶ a handful per group ▶ 40 CREDITS
- Paper ▶ 1 A4 size sheet per group ▶ 40 CREDITS
- Wooden skewers ▶ 1 package containing 60 pieces ▶ 5 CREDITS PER PIECE
- String, a thin wire or a thread ▶ 1 piece per group, length of 40 cm or so. Made from very thin material (0,3–0,8 mm diameter) ▶ Only one of these, not all ▶ 10 CREDITS PER PIECE
- A plastic cup ▶ a 140 ml coffee machine cup is perfect ▶ 1 piece per group ▶ 60 CREDITS

The rest is provided to each group (free of charge)

- Scissors ▶ 1 pair per group
- Eggs ▶ 1 egg (raw) per group
- A pricelist ▶ an A5 sheet of paper with materials and their hypothetical prices



PREPARATIONS

This exercise can be done outside or inside, without the need to modify any particular activities.

Preparations:

The students will be building a device to protect an egg and test the device by throwing the egg from a height. We suggest to throwing the egg from a regular school desk would be sufficient. The class should be organized so that the students can form groups of 3–5 members without interrupting each other. There should be a lot of planning and discussing within the group and it is important to ensure that groups does not copy the ideas of another. There will be a place reserved for the teacher who will be selling the materials needed for the exercise and will provide instructions to the informants (see exercise details). Please set up your shop with materials before the lesson starts and prepare pricelists for each group. You can use the pre-prepared pricelist in the lesson description part, or you can make one of your own.

A single place for dropping the egg should be prepared, avoid making the exercise too demanding as the point is not to develop perfect devices but to practice teamwork. We suggest 2–2.5 m height, which should correspond to a child/student standing on a school desk.

## ACTIVITY DETAILS

Prepare a special place for each group with one desk and several chairs, or don't use chairs and desks at all. The activity is suitable for outdoors as well. Prepare a place, serving as a shop, where all the materials can be purchased for hypothetical cash and where they are all visible.

*Description*

- Forming groups (5 min): Each participant draws a number from the hat. The number represents the group they will make (groups should not have more than 3 to 4 people). After the groups are formed, the students listen to instructions.
- Explain that the students will be dealing with a problem as a group. They have exactly 15 minutes to find a solution. First, ask them to pick a scout who will be told what the task is. Start the clock.
- Each group chooses a scout who is the only one who communicates with the teacher, and/or asks question if there are uncertainties, make purchases of materials, etc. He or she is given a pricelist, scissors and an egg. The work of the scout is part of the exercise. The idea is that a person with poor communication skills can delay the whole process and cause the group to lose precious time. Also, the group undergoes some first decision making – someone needs to decide who will go, who is best fit for the job. It also saves the teacher a lot of explanation and answering questions.
- The group learns that the goal of the task is to make a device which would allow an egg to land safely. If the egg breaks, the group losses the contest. They can buy the materials from the teacher according to the pricelist, using a hypothetical 100 (e.g. dollars) credits. If there any uncertainties, the scout has to go back and ask the teacher.
- The groups need to decide first what design they will prepare and consider their budget. How much can they afford and what can they make out of it? After they decide their final plan, the scout is sent to make the purchase (does not have to be the same person).
- The group works on the device with the egg. If they do not make it in time, they have to play with whatever they have prepared.

*Expected course*

What spontaneous dynamics and processes should take place?

- The group is made up of students who may not know each other well and so they may not be able to work together immediately. The purpose of the exercise is to change this, to learn how to work under moderate pressure and with people we do not know well.

## ACTIVITY DETAILS

- The group is expected to split roles due to deliberative, democratic decision-making. The group chooses a person who is capable of some diplomatic work – communicating with the teacher and then explaining the rules of the game. The rest of the roles are chosen operatively, actually it is expected to arise spontaneously. Someone will come up with a creative idea of how to solve the problem, someone will monitor the time and force the group to progress – taking a final decision, someone will calm others down and prevent the emergence of stressful situations.
- Group dynamics include constructing hypothetical design solutions (creative individuals), tracking time and game rules (gifted individuals), and moderating discussions and making final decisions (dominant or leading individuals). The roles are not expected to be fixed.
- The purpose of the exercise is that under the conditions of moderate stress there will be a natural expression of the dispositions and talents of the individual members of the group and thus the formation of a team. There will be a natural convergence in the group and an understanding of the differences.



## LOCATION

Indoor / Outdoor

## 4 | REFLECTION I.

## » QUESTION



The point is not to win, but to gain valuable knowledge about yourself and others.

The teacher will take a few minutes for a brief discussion with each group (or all together, depending on the conditions and time) – he/she asks them how they dealt with the task. What was the biggest problem and what helped to sort it out? How did individual members do and what roles did they have? What would they do differently? What did they learn?

ACTIVITY DETAILS



**LOCATION**

Indoor / Outdoor

5 | PRESENTATION

» DISCOVER 



**TOOLS AND MATERIALS**

- projector, PC
- [Advantage of symbiosis.ppt](#)

This points out the fantasy of nature and thus points out the wider context of the whole exercise (which the students have not yet realized). It is better that students come to these things themselves.



**PREPARATIONS**

Arrange the classroom for presentation.

The students have tried how they perform in a group. The assumption is that each member of a team assumes their natural role – what they are good at (especially when time is short!). A follow-up teacher presentation will expand on the topic of cooperation and labour division in nature, which will be demonstrated on the topic of symbiosis. Symbiosis is the cooperation of differently specialized organisms which benefits all its constituents. A model example of symbiosis is mycorrhizae – a cooperation between a plant and a fungus. While the plant excels at photosynthesis, the fungi is superior when it comes to extracting water and nutrients from the soil. This is why most plants have symbiotic relationships with fungi. Other examples of symbiosis should be presented as there are many.



**LOCATION**

Indoor / Outdoor

6 | REFLECTION II.

» QUESTION 

Ask the students about their perception of the importance of cooperation. Why is it better to do things together than doing them alone? Imagine your situation in a school. Should everyone be taught the same topics at the same time, or should individual talents be expressed instead? How should we think of efficient teams? Which members and talents should be included? Can you think of some examples of teams in nature? How about a troop of monkeys, antelopes, elephants, ant mounds, etc? Why do some animals have certain roles – does it have any relation to their predispositions?

LITERATURE, ADDITIONAL INFORMATION

Goodland, R. (1995). The Concept of Environmental Sustainability. *Annual Review of Ecology and Systematics*, 26(1), 1–24. doi:10.1146/annurev.es.26.110195.000245