Science in School
The European journal for science teachers

ISSUE 69 – September 2024 **Topics** Biology | Earth science | Science and society | Sustainability

Image courtesy of Tamaryin Godinho

Biodiversity and biomass in the school garden

Roberta Barbato

Small but mighty: investigate the role of herbaceous plants in the school garden for their contribution to biodiversity and sequestering carbon dioxide.

Introduction

Carbon dioxide (CO_2) constitutes about 0.04% of the atmosphere and is a greenhouse gas. CO_2 emissions have increased since the Second Industrial Revolution, contributing to anthropogenic global warming.Trees play an important role in sequestering CO_2, and it has been calculated how many trees are needed to support human activities,[1] but what about the role of herbaceous plants that grow spontaneously in courtyards or lawns in sequestering CO_2 or in contributing to biodiversity? By applying knowledge of biology and chemistry, through an inquiry-based learning (IBL) approach, it is possible to convey complex concepts[2] and achieve the following goals:

Learning objectives

- Apply the scientific method and use measurement procedures correctly
- Recognize the importance of binomial classification and systematics
- Collect and process data to draw conclusions and make comparisons
- Use digital tools and resources, including spreadsheets
- Consolidate theoretical knowledge in biology and chemistry by applying mole calculations

Cultural objectives

- Understand the concept of biodiversity
- Evaluate the importance of plants in their role of capturing the greenhouse gas CO_2

Students research in the school garden

Image courtesy of the author

The project is aimed at students aged 15–17. Ideally, they should already be familiar with taxonomic ranks; biomolecules and their chemical composition; the carbon cycle and photosynthesis; and moles, molar mass, and molar volume under standard ambient temperature and pressure (SATP).

Pl@ntNet is a citizen-science project for plant identification based on machine learning, and is available as an app. The Pl@ntNet app is a convenient tool to identify herbaceous species, but it is important to consider its reliability.[3–6]

It is important to analyze intact plants, preferably providing several photos showing different structures like leaves and flowers, otherwise the reliability of the Pl@ntNet application decreases. It is important to take good images that are well-framed and sharply focused. Results with probability of identification less than 60% are excluded.

Image courtesy of Tamaryin Godinho

Not only Pl@ntNet but also other apps like iNaturalist can be used to identify species.[7]

Activity 1: Biodiversity

The aim of this activity is to investigate the biodiversity of herbaceous species in a lawn or meadow, for example, in the school garden.

Students use an app to identify herbaceous species and determine their frequency in the sampled areas. They then create a digital herbarium and assign their own biodiversity index to compare the areas.

This activity is suitable for students aged 15–17 and takes approximately six lessons to complete.

Materials

- Per group: two wooden strips 51.0 cm long and two wooden strips 71.0 cm long (1.0 cm wide, 0.5 cm thick)
- Glue, possibly tacks
- Pl@ntNet app, which each student can download for free to their mobile phone
- Google Maps app, on the student's mobile phone
- Data table 1: Group data or spreadsheet version
- Data table 2: Class data or spreadsheet version
- Data table 3: Biodiversity index
- Data table 4: Class summary or spreadsheet version

Location notes

If the school lacks a garden or park, or if the existing one is too small to accommodate the biodiversity and biomass project, activities can be carried out with permission in a grassy area in a public or private park. Alternatively, a field that was once cultivated but has since been left to lie fallow could be used. The key is that the plants present should not have been intentionally sown but should be the result of spontaneous herbaceous growth, and human intervention should be limited to occasional mowing. If no areas with these characteristics can be found, then areas with more significant human intervention can be used. However, it is essential to highlight this aspect for students. This will enable a discussion on the impact of human activities on biodiversity and the importance of preserving natural areas.

Procedure

Note: printable data tables are provided but processing the data will be much easier if spreadsheets are used after the initial data recording.

Lesson 1

1. Divide the class into groups, each consisting of three or four students.
2. Each group of students sets up their own rectangular template, gluing the wooden strips together or attaching them with tacks in such a way as to obtain a rectangle with a final size of 50 cm × 70 cm.
3. In the garden, each group places their template randomly on the lawn and spaced apart to sample different areas.

Sampled area

Image courtesy of the author

4. Each group should use the Pl@ntNet app to identify the herbaceous plants within their sample area (family, genus, species). Sometimes, to facilitate identification, it may be necessary to image the plant after removing it and positioning it horizontally on a rigid support (a tray, a notebook, a bench…). Each group preserves the photos.
5. Each group lists the genus, species, and family found in the examined area. Data table 1 can be used for this, or students can just make a list in a notebook.

An annotated screenshot of ID results from the Pl@ntNet app

6. Optional: at the end of the activity, one student in the group positions themselves inside the template and notes the geolocation by taking geographical coordinates using Google Maps or another app with a mobile phone. This could be useful if one intends to carry out future studies of biodiversity changes over time.

Lesson 2

7. In the classroom, each group reorders its data, grouping species belonging to the same genus and grouping genera belonging to the same family. Entering the data into a spreadsheet facilitates the reordering activity.

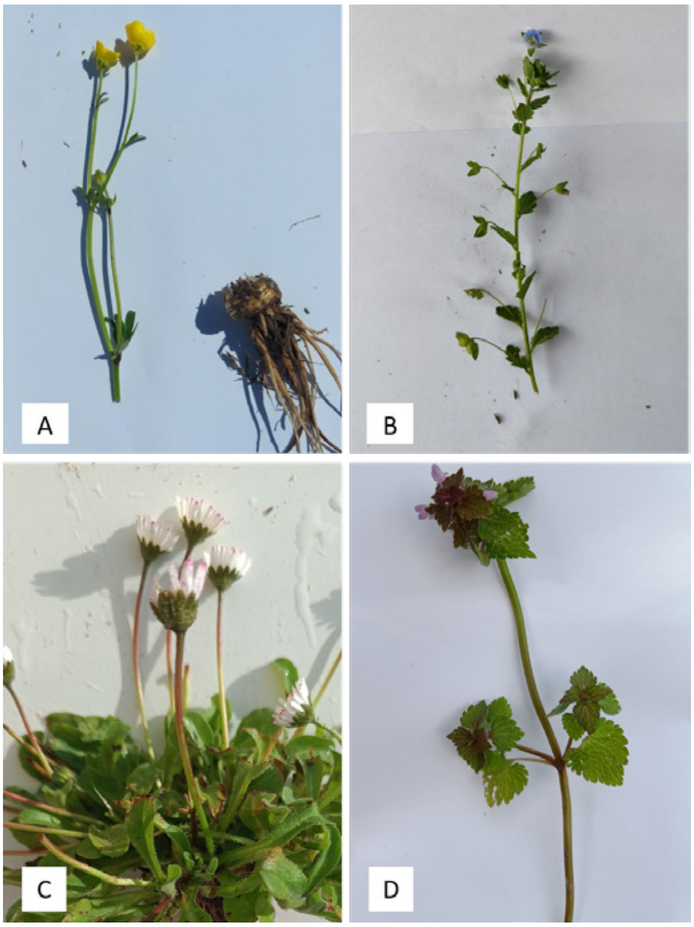
8. Some online research is helpful at this stage, for example, to broaden one's knowledge of the distribution of that species in Europe or the characteristics of that species, or to check identifications. There are free-to-access websites that provide a wide range of biodiversity data, including information on plant characteristics.[8,9]

Lessons 3–4

9. All groups share their results to compile a single class list of identified species and families (Data table 2 or spreadsheet version). Frequency, that is, the number of sample areas where each species is detected out of the total number of areas, can give an idea of their prevalence in the whole garden. Data table 2 can be completed by sharing it on a drive.

Species	No. of sample areas out of a total of	Family

10. Students compare photos of herbaceous plants and choose the best photo for each species, which is named according to binomial nomenclature and then uploaded to the shared Digital Herbarium folder.



Photos in the Digital Herbarium: *Ranunculus bulbosus* (A), *Veronica arvensis* (B), *Bellis sylvestris* (C), *Lamium purpureum* (D)

Image courtesy of the author

Lessons 5–6

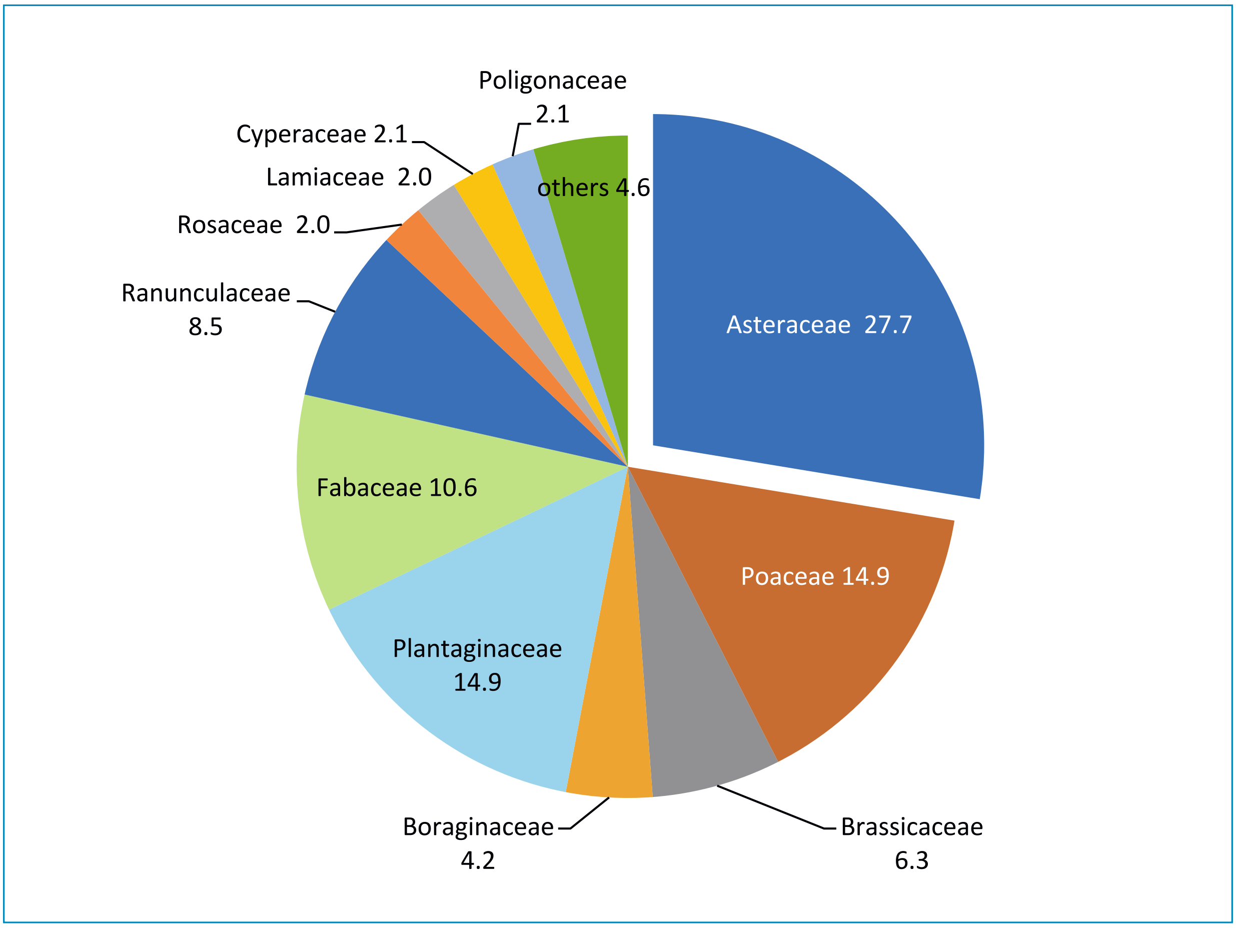
11. Each group discusses and proposes a rudimentary biodiversity index to assign to the sample area.
    Creating a biodiversity index is a complex task that requires careful consideration of many factors. Before the discussion, the teacher could introduce biodiversity indices and help students to consider the data they have. What do they measure? Number of species, genera, or families present (richness)? Or their relative abundance (evenness)? What assumptions will the index make about the data?
12. As a class, the students discuss the various biodiversity indices proposed and choose the most suitable index for the type of activity they have carried out.
13. Each group should apply the index to their own area (reordered spreadsheet from step 6). By comparing the values, the students should recognize that there are areas with greater biodiversity than others (Data table 3).

Sample area no.	Biodiversity index

14. Students complete a summary of class sampling (Data table 4 or spreadsheet version), which highlights the most represented families and genera. This table could also be useful for comparing the results between different classes and in different periods.

Family	Different biological genera (number and name)	No. total species

15. Students process and represent data with graphs, for example, bar graphs can be used to compare the abundance of different species, genera, or families in the various sampling areas. Pie charts are effective for showing the proportion of each taxonomic group within the sample. Line plots can illustrate changes in species abundance over time or between different sampling sites.



Biodiversity as % species versus family (data from Data table 3)

Image courtesy of the author

Results

An example dataset is shown in the supporting material. Below are the processing results.

Data table 3: Biodiversity index.

Sample area no.	Biodiversity index	
1	7–11	*The biodiversity index the students have chosen here is represented by two numbers: the one preceding the hyphen indicates the number of families in the sampled area; the one after the hyphen represents the total number of genera in the sampled area.* ***Area No. 3 has greater biodiversity than the others.***
2	7–11	
3	10–17	
4	6–09	
5	7–14	
6	6–09	

Data table 4: Summary of the whole-class sampling.

Family	No. of genera (list them)	No. of species
Asteraceae (or Compositae)	7 (*Bellis, Crepis, Hypochaeris, Lactuca, Leontodon, Sonchus, Taraxacum)*	13
Poaceae	6 (*Agrostis, Brachipodium; Eragrostis, Lolium, Phleum, Poa)*	7
Brassicaceae	3 (*Arabidopsis, Cardamine, Capsella)*	3
Plantaginaceae	2 (*Plantago, Veronica)*	7
Fabaceae	2 (*Medicago, Trifolium)*	5
Boraginaceae	2 (*Myosotis, Symphitum)*	2
Ranunculaceae	1 (*Ranunculus)*	4
Lamiaceae	1 (*Lamium)*	1
Rosaceae	1 (*Potentilla)*	1
Cariophyllaceae	1 (*Cerastium)*	1
Cyperaceae	1 (*Carex)*	1
Marsileaceae	1 (*Marsilea)*	1
Polygonaceae	1 (*Rumex)*	1
Total	**29 genera**	**47 species**

Discussion

Below are examples of questions to consider by looking at the data:

- What was the most widespread family?
- What biodiversity index was proposed? Can you think of alternatives? How do they differ?
- Were there areas in the garden with greater biodiversity than others?

For example, after analyzing and discussing the example data shown above, students concluded the following: Sample area No. 3 has greatest biodiversity (Data table 3). The presence of different species in the sample areas shows that the garden is not homogeneous, and thus, confirms the spontaneous origin of the plants. Sporadic cutting and low maintenance allow the establishment of many herbaceous species, generally considered weeds, which are carriers of great biological diversity.

Activity 2: Biomass and CO_2

The purpose of this activity is to investigate the biomass of a lawn. Students calculate how much CO_2 has been removed from the atmosphere to constitute the organic above-ground part of the grass/plants present in 1 m^2 of lawn or garden by applying a mole quantity calculation.

This can be carried out in any area that hasn't been mowed recently. For practical reasons, if the quantity of plant material taken from the rectangular sample is large, it will not all be dehydrated. Three small portions are easier to handle and dehydrate.

This activity is suitable for students aged 15–17 and takes five lessons to complete.

Materials

- Technical balance, sensitivity 0.01 g
- Rectangular template (50 cm × 70 cm) for each group, as in Activity 1
- Scissors
- Tray or a plastic bag/group
- Three small slotted baskets (6.5 cm × 8.0 cm) for each group of students or each class

Procedure

Lesson 1

1. Divide the class into groups, each consisting of three or four students. Alternatively, larger groups may be used or a single sample area may be investigated for the whole class, depending on the availability of materials and space to carry out drying.
2. In the garden, each group places the rectangular template randomly on the lawn and spaced apart to sample different areas.
3. Using scissors, cut off the aerial and green parts of the grasses/plants within the template, basically shaving the plants at ground level. The lawn must be dry: the early hours of the morning should be avoided due to condensation.
4. Collect the cut grass/plants over a previously weighed tray or in a plastic bag.
5. Use a balance to determine the gross weight of the cut sample.
6. Number the small baskets and determine the tare weight of each.

Some stages of the procedure (steps 2, 3, and 6)

Image courtesy of the author

7. Remove three different aliquots of freshly cut grass (ranging from 19.00 g to 40.00 g), place them in the small baskets, and record their gross weights.
8. Store the baskets in a heated and well-ventilated place.

Lessons 2–3

9. Every day (or every two or five days), students monitor the decrease in gross weight and record the value until complete stabilization is achieved. To speed up the time, a laboratory stove can be used if necessary. Since the water content is approximately 78% m/m, a high gross weight loss is expected.

Lessons 4–5

Notes

- The % m/m of the carbon element in the dried organic matter is considered to be 46% m/m.[10,11]
- There is a difference in the volume of one mole of gas under standard temperature and pressure (STP) and under SATP conditions. The volume under SATP is 24.79 mol/l, but 22.4 mol/l under STP.

10. Each group prepares a table or Excel worksheet to determine the percentage of water and average dry biomass percentage for the three baskets and proportionally obtain the dry biomass percentage of the entire sample area.
11. In the Excel worksheet, students determine the number of moles of carbon atoms in the biomass; this is the same as the number of moles of CO_2 molecules absorbed to produce it.
12. From the mole quantities, students complete a table or Excel worksheet to determine the grams and litres of CO_2 under SATP conditions that have been sequestered from the atmosphere and fixed in 1 m^2 of biomass.
13. Finally, all groups come together to compare data and discuss their results.

Example of results of calculations by a group of students using an Excel spreadsheet.

Dry biomass in sample area (g)	C in sample area		CO_2 in sample area		SATP CO_2 in sample area (litres)	CO_2	
	(g)	(mol)	(mol)	(g)		(g/m^2)	(l/m^2)
52.11	23.97	2.00	2.00	87.89	49.54	252.12	141.54

Results

Below are examples of the data collected and results of its processing. The activity was carried out on three different dates, from April to May, by three different classes of students.

Example data: biomass and CO_2.

Sampling date	Water (% m/m)	Dry biomass (g/m^2)	CO_2 (g/m^2)	CO_2 (l/m^2)
10 April	77.18	86.91	146.58	82.58
18 April	77.23	127.51	215.06	121.22
4 May	78.36	257.96	435.10	245.13

- The average percentage of water in the grass is 77.59% m/m.
- The amount of CO_2 removed from the atmosphere and transformed into organic matter is 215.06 g/m^2, equivalent to 121.22 l/m^2 (SATP), on 18 April, increasing to 435.10 g/m^2, equivalent to 245.24 l/m^2, by May.

Discussion

Students calculate the number of moles of carbon in the biomass then, knowing that one mole of carbon comes from one mole of CO_2 through photosynthesis, they determine the grams and litres of CO_2 that have been removed from the atmosphere. The teacher collects the Excel worksheets, checks the procedure and the results obtained, and discusses with the class if there are errors.

Note that the calculations underestimate the absorbed CO_2 because only the aerial parts of the plants are used and we don't consider the root biomass. The data demonstrates the importance of herbaceous plants, which, growing spontaneously in uncultivated land, trap CO_2 very effectively, thanks to their fast growth.[12]

The results only provide information about the sampling instant. Subsequent studies could aim to find the correlation between the amount of CO_2 that is converted into biomass over a time interval (e.g., a month or a season) in association with factors like the average temperature, relative humidity, precipitation, and light intensity on the school lawn. «

Acknowledgements

Thanks to the students of the 2nd C and 2nd M classes at the scientific high school "Liceo Statale Galileo Galilei" (Dolo, Venice), who worked hard and were the first to experiment with Activities 1 and 2 in the 2022–23 school year. I also thank my former colleague, high school teacher Elisa Cappelletto, who initially collaborated on the realization of the project with the 2nd F class.

Cutting-edge science: related EIROforum research

European Molecular Biology Laboratory (EMBL)

EMBL

The Global Biodiversity Data Portal
Image: Karen Arnott/EMBL-EBI

The European Bioinformatics Institute (EMBL-EBI) has launched the Global Biodiversity Portal, an open-access platform that brings together genomic data from different biodiversity projects within the Earth BioGenome Project. The portal enables global biodiversity research by providing centralized, accessible data for understanding the genetic uniqueness and adaptability of species and supports practical applications, such as agriculture and bioengineering. The portal simplifies access to genome sequence data and allows users to easily search for species information.

www.embl.org

References

[1] Schwarz A et al. (2024) How much carbon is locked in that tree? *Science in School* **67**: 1–7.

[2] Wahyuni L et al. (2022) The effect of guided inquiry learning model through the utilization of school environment towards students' scientific literacy on biodiversity concepts. *International Journal of Biology Education towards Sustainable Development* **2**: 44–52. doi: 10.53889/ijbetsd.v2i1.131

[3] Affouard A et al. (2021) Customized e-floras: how to develop your own project on the Pl@ntNet platform. *Biodiversity Information Science and Standards* **5**: e73857. doi: 10.3897/biss.5.73857

[4] Pl@ntNet: an app to advance botany: https://www.cirad.fr/en/our-activities-our-impact/our-impact/success-stories/pl-ntnet

[5] Affouard A et al. (2023) Pl@ntNet observations. Pl@ntNet. Occurrence Dataset. doi: 10.15468/gtebaa

[6] Joly A et al. (2016) A look inside the Pl@ntNet experience. *Multimedia Systems* **22**: 751–766. doi: 10.1007/s00530-015-0462-9

[7] Echeverria A et al. (2021) Learning plant biodiversity in nature: the use of the citizen–science platform iNaturalist as a collaborative tool in secondary education. *Sustainability* **13**: 735. doi: 10.3390/su13020735

[8] GBIF: Global Biodiversity Information Facility: https://www.gbif.org/

[9] Index of botanical species present in Italy: https://www.actaplantarum.org/flora/flora.php?m=0

[10] Ma S et al. (2018) Variations and determinants of carbon content in plants: a global synthesis. *Biogeosciences* **15**: 693–702. doi: 10.5194/bg-15-693-2018

[11] The types and characteristics of biomass (table on p 18): http://bioenergy-fvg.uniud.it/fileadmin/documenti/Corso_energie_rinnovabili/Le_tipologie_e_le_caratteristiche_delle_biomasse.pdf

[12] Di Vita et al. (2017) A review of the role of vegetal ecosystems in CO_2 capture. *Sustainability* **9**: 1840. doi: 10.3390/su9101840

Resources

- Learn more about different uses of herbarium collections and their associated data.
- Learn how the places where we preserve biodiversity have changed over the centuries. (Italian)
- Explore some resources to bring the science of sustainability into the classroom: Philippsen M (2024) Sustainability in the classroom: teaching materials from Science on Stage. *Science in School* **66**.
- Use geometry to estimate the CO2 absorbed by a tree in the schoolyard: Schwarz A et al. (2024) How much carbon is locked in that tree? *Science in School* **67**.
- Discover the challenges of genome sequencing: Dyer S, Jackson B (2024) Plant genetics: explore DNA extraction and the challenges of gene sequencing. *Science in School* **68**.
- Grow bacteria from ants' feet and learn how they could help us reduce the use of chemical pesticides: Jensen IC (2024) Footprints in the agar: growing bacteria from ants' feet to combat plant diseases. *Science in School* **67**.
- Learn about the ocean and how it affects our lives through engaging classroom activities: Realdon G (2023) Practical ocean literacy for all: ecology and exploration. *Science in School* **64**.
- Embark on a microscopic moss safari to explore the fascinating world of diverse and resilient organisms that thrive in this challenging habitat: Chandler-Grevatt A (2023) Moss Safari: what lives in moss? *Science in School* **63**.
- Discover how trees use chemicals to communicate with soil microbes: Rumeau M (2024) Exploring the dialogue between trees and soil microbes. *Science in School* **68**.
- Discover how the unique characteristics of seagrasses are vital for the health of our planet: Crouch F (2024) Seagrass the wonder plant! *Science in School* **67**.
- Learn about how trees affect the climate: Harrison TG, Khan MAH, Shallcross DE (2022) How trees affect the climate: is it just through photosynthesis? *Science in School* **58**.
- Read about the first land plants and how they changed our world: Streubel S (2023) When plants moved ashore and changed the planet. *Science in School* **64**.

- Find out about the feuds between plant and pathogen that span millions of years: Harant A, Pai H, Cerfonteyn M (2023) Plant pathology: plants can get sick too! *Science in School* **62**.
- Learn about bioinformatic data storage at EMBL-EBI: Stroe O (2018) Bioinformatics: the new 'cabinet of curiosities'. *Science in School* **44**: 20–24.

AUTHOR BIOGRAPHY

Roberta Barbato has a degree in biological sciences and a PhD in molecular and cellular biology and pathology from the University of Padua (Italy). She has taught at various high schools and currently teaches natural sciences (biology, chemistry, and Earth sciences) at the Galileo Galilei Scientific High School in Dolo (Venice). She is interested in transmitting knowledge by actively involving students and challenging them to apply the scientific method.