SCIENTIFY

ENGAGING WAYS TO SCIENCE: EMPOWERING PROJECT-BASED LEARNING FOR INTERDISCIPLINARY SCIENCE EDUCATION

Co-funded by the
Erasmus+ Programme
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scientify

All the materials of this collection have been designed and tested by the participating teachers of the partner schools.

The project has been founded by the Erasmus+ Programme of the European Union.

If you want to know more, please visit our website: www.scientify-erasmus.net or contact the project coordinator: alheid.szellinski@voss-schule.eu

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Introduction

Partnership

During 2020-2022, partner schools from Germany, Hungary, Lithuania, and Portugal implemented the Erasmus+ School Exchange Partnership Project (KA2) "Engaging Ways to Science: Empowering Project-based Learning for Interdisciplinary Science Education". The motivation of JHVS (DE) and other partner schools (LT, PT, HU) to set up this project was fuelled by the need to get more opportunities to cooperate and provide deeper and more rewarding student experiences beside the higher engagement in the Science learning-teaching process both for educators and students. Thus the aim of the participating schools was to exchange experiences and get new ideas to empower project-based learning as an approach for a more engaging interdisciplinary Science education.

The teachers participated in four International Teachers' Rooms on guidelines for project based learning and using films/videos, Science study circle methodology and cooperation with English/Literature teachers for preparation of activities to analyse science books/articles with students, generating ideas for thematic real-life based interdisciplinary projects and organizing short-term projects, as well as applying assessment techniques.

Our main aim was also related to the exchange of good practices, improvement and development of activities based on a project approach to be integrated into the curriculum for teaching Mathematics, Physics, Biology, and Chemistry. Based on the training experience, using skills and knowledge from transnational activities schools were organizing their own short-term projects, choosing and testing some parts of partner implemented projects following the topics discussed. They were developing model projects together, sharing interdisciplinary Science project descriptions, providing colleagues with feedback. Their learnings resulted in a collection of Science project examples (activity plans as the steps and material how to implement the short-term projects) for further application in schools.

The collection of the material in this book is an example of what can be achieved working internationally and that different cultural perspectives add to a variety of ideas, cooperation helps to increase credibility (schools from four partner countries, choosing project-based learning as a pathway to better Science education demonstrated that such successful initiatives are not limited to one country), results in higher interest, motivation and inclusion (the integration of project-based learning into respective curricula units and the added European value helped to provide a more constructive teaching/learning process).

Aim of the book

This book is intended for teachers and provides descriptions of successfully implemented short-term Science projects.

It furthermore emphasizes that focusing on interdisciplinarity while teaching Science should be reinforced by adding the project-based learning approach, as they are a natural fit and highly complement each other. The project approach is meant to shift away from present classroom practices and instead emphasize learning activities that are longer-term, interdisciplinary, student-centered, and integrated with real-world issues and practice. Thus the material and ideas for a project week "Discover and Uncover with Science: Everyday and Nature Phenomena" activities in this publication illustrates how to follow aforementioned ideas, aims and methodology.

The interdisciplinary short-term project approach model is at the centre of the project examples presented in this book. The descriptions/scripts of projects/activities based on and incorporating chosen science fiction films such as "Gattaca"(1997), „Spider-Man 2"(2004) and "The Martian"(2015) for teaching/learning Science emphasizes the more engaging ways to increase content retention, motivation, reinvigorate teaching and recognize the importance of internalizing and contextualizing information in meaningful ways.

Also, the example of the Science Learning Circle based on reading/analysing Science articles and aimed to support and organise engaging Science (Mathematics, Physics, Chemistry and Biology) teaching/learning activities is given in this book. It has been a relatively new type of a short term project applied in the partner schools and proved to be

really useful for empowering students to shape their learning experiences and embed 21st century success skills like collaboration, creativity, critical thinking.

We hope this publication will become the source for new ideas and aspirations to design, organise and develop engaging experiential activities for Science teaching in order to provide learning that maximizes student potential.

Participating Schools

Johann-Heinrich Voss-schule

Johann-Heinrich-Voß-School is one of the two grammar schools in Eutin, a town in northern Germany with about 18, 000 inhabitants. We lead our pupils (aged 10-19) to their A-levels in 8 resp. 9 years.We have about 550 pupils, 44 permanent fully qualified secondary school teachers and usually 3 student teachers as well as one social education worker. The level of schooling is quite high; in the years 5-10 we offer a wide range of subjects, covering languages (German, English, Latin, French), natural and social sciences, art, sports and music. This then is the comprehensive foundation for our work in the last three years of the sixth form. Here students can choose between certain profiles with emphasis put on either natural/social sciences or on languages. Most of them later go on to university. Our formal education shows very good results as is also shown by numerous awards our pupils quite regularly obtain in national contests. We engage our students in all fields of our educational curriculum, which is supported by various extracurricular activities (sports; school orchestras; musical and drama groups; exchange programmes).

Contact details

School principal: Tanja Dietrich

Project coordinator: Alheid Szellinski

Website: www.voss-schule.de

Agrupamento de Escolas Daniel Sampaio

AE Daniel Sampaio is a public educational organization with 7 different units from kindergarten to upper secondary school, with 3000 students, and a centralized management. For this project, we are aiming for the secondary school which is part of the head unit. Our school, the head unit, has 1000 students and 100 teachers, and it's located in the suburban area of Lisbon in an administrative region of 174 000 inhabitants, working mainly in the sector of services. On the general level, the school has been building their international program for the last 18 years through former Comenius and Erasmus+ KA2 multilateral partnerships, together with bilateral partnerships for student exchanges, having then a long and rich experience, documented in www.clubeuropeu.wordpress.com. On the specific level, being a school with a long tradition both on science programs and international ones,

it was a success to have joined several E+ KA2 partnerships, which allowed the school to engage, science teachers and students in a science curricular projects; plus, the interdisciplinary dimension added to these projects will enhance the attractiveness of science teaching/learning, aiming more task and project-oriented methodologies, which are not unknown to school as the interdisciplinary practice a core part of its Educational Project and a main drive in the national curricula.

Contact details

School principal: Sara Moura

Coordinator: Fernando Rebelo

Website: https://ae-danielsampaio.pt/website/pt

Jedlik Ányos Gimnázium

General information

Our school is a prestigious institution in Csepel, Budapest, highly appreciated by the local community. Generations of families come to this school and many colleagues have also been teaching here since the beginning of their careers. The number of teachers is 64. On average 700 students attend our school and each year 78% of the schoolleavers continue their studies at universities. Most of our students take part in a 4-year course between the ages of 14 and 18. On the 4-year courses, students can specialize in Sciences, Languages, IT or Sports. All the students learn two foreign languages, which they can choose from English, German, French, Italian and Spanish. We are proud of our students' great successes in both national and international competitions and the school's international relations that date back to 1984.

Sciences and languages

The school has a strong academic background in both teaching sciences and language acquisition which are the key areas of the Scientify project. Our students participate in numerous national science and language competitions, furthermore, we organize a yearly contest for our local partner schools on physics. The science department organizes the Project Week of Sustainability every year and the school is equipped with a professional laboratory for teaching sciences.

International experiences

International relations have always played a significant role in the school's life. Some of them are regular and some take place occasionally. We have participated in different educational programs of the EU (Comenius, Erasmus+) Currently we run two student exchanges with the Gymnasium Holthausen, Hattingen (DE) and with the Escola Secundária Daniel Sampaio, Almada (PT). These programs enable 30-40 students every year to practice languages and get acquainted with different cultures. Kielce (Poland) is the twin city of Csepel, that is the reason why from time to time common projects are carried out, often with the participation of our students.

Contact details

School principal: Bese Benő

Project coordinator: Kohut Judit

Website: www.jedlik.hu

Pakruojis "Atžalynas" Gymnasium

Pakruojis " Atzalynas" Gymnasium is providing secondary and non-formal education for over than 300 students of 1-4 classes (aged 15-19). Our gymnasium is the only purified gymnasium in Pakruojis district. 39 high - qualified teachers are working in the Gymnasium. 26 of them have a teacher methodologist qualification category. There is also a social educator, a psychologist, 2 headmaster's assistants. Teachers of Biology, Mathematics and Chemistry (4), deputy heads of the gymnasium (2) who are also specialists of IT, Physics and Chemistry, the highly qualified English language teachers (2) were involved in carrying out the project. They have a great experience in national projects and some of them in international (Comenius, Erasmus+ KA2 strategic partnership for schools) projects. The majority of them have participated in partnership activities related to strengthening the learning process and interdisciplinarity for teaching Science. The science teachers have great experience in involving students in a learning process creatively. The teacher of Maths is experienced in creating a learning environment through the utilization of technology and organizing national events both for teachers and students. The teachers have great cooperation skills, are well organised, able to work in a team, have IT skills, are open-minded and communicative. Science teachers develop common ideas with the teachers of English and organize activities based on CLIL methodology. They also involve students in

organizing short-term projects and classes based on an interdisciplinary approach. The understanding of quality in the educational process of teaching science is the agreement between the school community members. To reach better results teachers use various innovative methods and their experience from different projects. The participation in the project for strengthening the project-based learning and higher-level interdisciplinarity in teaching Mathematics, Physics, Biology and Chemistry has been a great input into their efforts to make the teaching and learning process a success while being able to learn more, share and apply the most acceptable and value-added approaches.

Contact details

School principal: Mrs. Asta Valuntienė

Project coordinator: Ms. Rima Leimontienė

Website: www.atzalynas.net

„Films and Science Laboratory" activity

The Martian

COUNTRY: Hungary

SCHOOL: Jedlik Ányos Gimnázium

SUBJECTS/TEACHERS: Brutovszky Gabriella – Biology
Hortobágyiné Kard Eszter – Math, IT
Nagy Andrea – English
Zaha Enikő – Chemistry, Physics

Movie	The Martian (2015)
Title	How to survive on Mars?
Level (age of students)	10th grade (16-year-old students)
Equipment needed	Projector, computers Lab materials *Optional: Robots (eg. LEGO), 3D printer*
Teaching aims	**Biology**: Nutrition, carbohydrates, mono- and polysaccharides **Chemistry**: Types of chemical reactions, stoichiometric calculations, starch properties **Physics:** Vibration and waves, Deflection, Mechanics of fluids **Maths:** Hexadecimal and other number systems **IT:** programming robots, modeling in 3D **English:** Job advertisement, Job interview; CV, Cover letter and Scientific vocabulary of the topic
Methodologies/methods	Group work Practical work Research Experiment Discussion
Activity phases and timing	Lesson 1: Introduction Lesson 2-4: Group work + homework Lesson 5-6: Presentations Lesson 7: CV and job interview Lesson 8: Conclusion and (self)evaluation

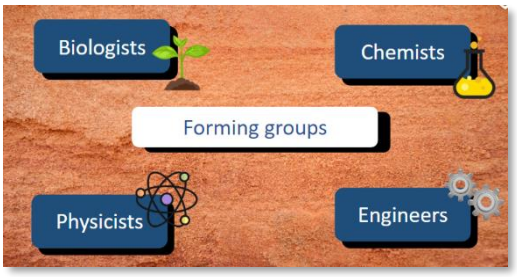
Intro

Imagine that you are a member of the team which will colonize Mars!

What should we do to make this planet livable? What difficulties do we have to solve?

Descriptions of the activities

In the 1st lesson we introduce the project to the students. We form 4 groups by fields of sciences. We will have biologists, chemists, physicists and engineers.



Every group will work on its own tasks in the next 3 lessons. They also have some homework in this project because not all of the tasks can be executed in the lessons. After the group work they will present their results to the others. In this lesson they have to figure out the requirements of what they expect from other groups about their presentations. This way the teachers can prepare the final evaluation form using the student's own ideas.

These tasks are suggestions, teachers or students can pick from them as they like.

Biologists tasks

"I will survive" Biologists will find out how and what we can plant in the "space soil". Prepare 3 types of soil model: soil mixed with manure, regolith (sandy soil, gravelly soil) and a mixture of these two! Plant 3-4 types of plants: potatos, oilseed rape, radish, peas! Observe how these plants are growing and draw some conclusions. Find out what conditions are necessary for the plants to sprout and grow (light, temperature, water) and prepare a laboratory report! (*Annex 1*)

"Eat like a Martian!" Were you thinking about how much should we eat on Mars? Our biologist team will answer this question! Necessary daily calory intake for women and men on Earth and Mars depending on age, physical activity requirements. How much calory intake is required to spend a whole year on Earth- and Mars! How much starch or glucose do we need to meet our daily energy needs? Can you recommend other options? (E.g. eating insects, cell-based food (as part of the food supply etc.)

"Be or not to be...starch in my food" Why do we need starch on Mars? Experiment! What contains starch? Test for the starches in food! Select foods (as many as possible) in which you can test for the presence or absence of starch using iodine. Look for fake products (for example sour cream). Perform an adulteration test to prove that a fake product is being sold.

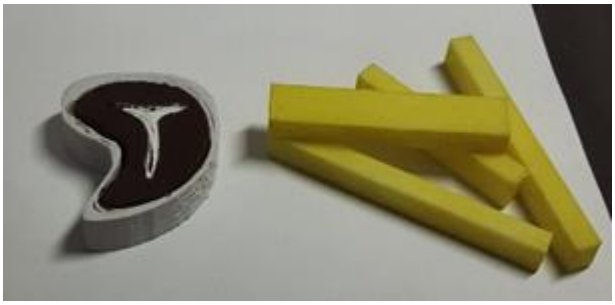
"With or without…sugar" Why is starch important as an energy source on Mars (too)? How can our bodies break down starch? Experiment! Demonstrate the breakdown of starch using enzymes! Benedict's Test for Reducing sugars biochemical:

- How do you do a Benedict's test for reducing sugars?
- What colour does Benedict's turn when glucose is present?
- Which carbohydrates give a positive Benedict test?

Engineers' tasks

„Mysterious sixteen" Were you thinking about how we could transfer short messages if we could only rotate the "head" of a robot? You can get an idea from the movie The Martian. The Pathfinder robot does exactly this. Your task is to find a way to code the letters into numbers and show these messages in some way. You can use a LEGO Mindstorms robot to demonstrate this process. Or you can realize any other ideas, for example a program you write (e.g., in Python, JavaScript, Scratch etc.)

„3D-spaghetti" Make research about 3D printing! How does it work? Search the website tinkercad.com! Use the included shapes and design some food (e.g., pasta) in 3D and print it! You can design a house number plate, too! Be creative, maybe somebody in the future on Mars will print this for their house! 😊 If you are brave, you can design a whole Mars-house too!



„Colonize Mars!" Design a city on the Mars! Make also a small research before starting. Some questions that may help you:

- How should the homes look like? What is difference between the houses on the Earth and on the Mars? What problems do we have to solve when we build a house on the Mars? Think about the Hab (QR code) where Mark lived in the movie!
- What kind of institutions do we need on Mars? Are they different from the ones on Earth? For example how should a mall or a „gas station" look like?

Make a digital poster about it! You can use any program you already know or search for one on the internet!

Physicists' tasks

„Proof of gravity" Build a pendulum.

„Step by step on Mars" Model the quicksand: make non-Newtonian fluids.

„Visit the Red Planet!" Use the following table and questions to make an exciting presentation about Mars.

Featuring	Earth	Mars
diameter	12 756 km	6794 km
mass	$5{,}974 \cdot 10^{24}$ kg	$6{,}4185 \cdot 10^{23}$ kg
rotation time around the axis	23 hours 56 min	24 hours 37 min
average solar distance	149 600 000 km= 8,3 light min	227 900 000 km= 12 light min
time period around the Sun	365,25 day	1,88 Earth year
axial velocity	23,5°	25,2°

- How long is a Martian day (called sol)?
- How long is a Martian year?
- What is the reason for the seasons in some of the Earth's climates?
- Are there any seasons on Mars?
- The distance between Earth and Mars is not a constant number. At what interval does it vary (in light minutes!)?

- How long does it take for a message to get from Earth to Mars?
- What would your weight be in that spaceship going to Mars?
- Why is Mars red coloured?
- How would a traditional or digital kitchen scale be used on Mars?

„Build your own spacecraft" Build a spaceship from PET bottles. You can find an example in this link.

Chemists' tasks

„Be the best water-maker!" During the Mars expedition, we will need water. Briefly demonstrate the production, physical and chemical properties of hydrogen using experiments.

- What methods can you use to produce hydrogen?
- What chemical process does Mark use to create water?
- How can you test for the presence of hydrogen gas?
- What is the name of the test of hydrogen gas?
- How much water do we need? (This example is taken from the movie.) If we plant 126 m^2 of crops and we know that 1 m^3 of soil requires 40 liters of water per day to grow potatoes. Calculate how much water we need to produce each day for watering!

The last section of the project

In the next two lessons the groups can present their results to other groups. They can do some experiments in real time or showing these experiments in short videos. Some topics also need a presentation or a digital poster.

In the last lesson of this project the students will take part in an English lesson. (*Annex 3*)

NASA is highly satisfied with your achievements and wants to recruit more astronauts. Your tasks:

- Write the JOB ADVERTISEMENTS and decide on the positions, description of the job and skills.
- Make a QUIZ, using second conditional to find out what their skills are.
- Call them for A JOB INTERVIEW and decide who you will employ.

Evaluation

After this long project we evaluate different points of view.

The teachers fill an evaluation form for each student. In this form the teachers can pick some headlines about what the student adds to the success of the project and what he/she can improve. The teacher can write some short sentences about the performance of the student during this group work.

Name		**Group**	
Class			

What did you add to the success of the project					
Engagement	Cooperation	Communication	Flexibility	Creativity	Task management
Explanation:					

You can improve this field					
Engagement	Cooperation	Communication	Flexibility	Creativity	Task management
Explanation:					

Date:

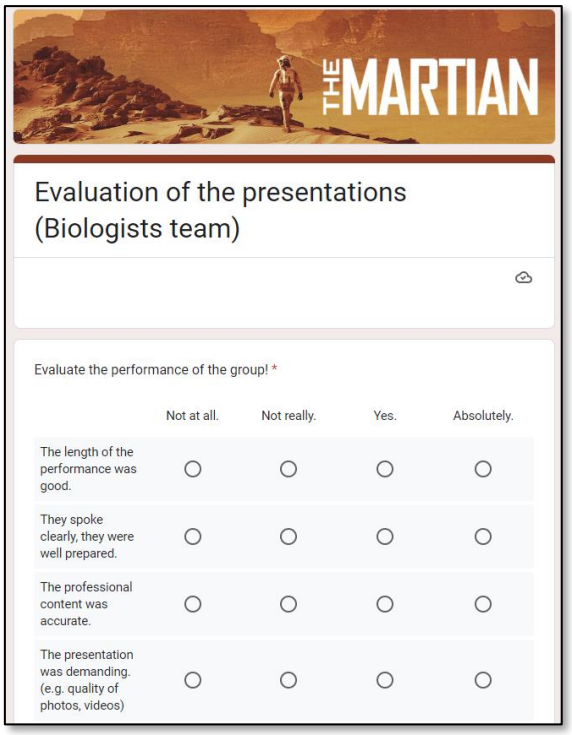
Signature

I have read and accepted

Student's signature

Remark:

The students can evaluate the performance of the other groups according to the aspects they wrote in the first lesson. The best way to do this is filling an online form.



Annex 1 – Planting Protocol

Planting kitchen garden plants – „Martian” project

The protocol is completed by:

Plant species to be cultivated:

General characteristics (any important information about the species):

Worksheet of the plant being planted

Planting depth of seeds	Spacing between seeds	Temperature requirement	Water requirement	Light requirement	Soil requirement	Breeding time

Planting and monitoring

Soil types	Planting date	Week 1	Week 2	Week 3	Week 4	Week 5
General potting soil (composition: ……. ……. …….)						
Fertilized potting soil (composition: ……. ……. …….)						

Sandy soil modelling Regolith soil (composition: …… …… ……)						

Hypothesis:

Summary based on observations:

Pictures of the process (from planting, sprout growth to eventual harvest):

Annex 2 – Tasks for the engineers

TASKS FOR THE ENGINEERS

IN MARTIAN PROJECT

1. **"**MYSTERIOUS SIXTEEN**”**

   Read the QR-code and watch this scene from the movie!

   After watching answer the questions!

   a. How did the Pathfinder robot transfer messages?

   _____

   _____

   b. What is the name of the code table what Mark and his colleagues used to code the letters into numbers?

   _____ -table

   c. Complete the table!

Character	Decimal code	Binary code	Hexadecimal code
A			
b			
	108		
			2E
[SPACE]			
		1010100	

   d. What is the advantage of the hexadecimal codes? Why did they use that instead of binary?

   _____

   _____

   e. Use the hexadecimal codes and code the word: „HELLO”!

   _____

   f. Decode these messages!

   4D415253 _____

   7370616365 _____

   g. Work with your group and try to build a Pathfinder! You can draw a circle like Mark and rotate a flag with your own hands but if you have the opportunity, you can also use a robot (e.g. LEGO Mindstorms), or write a program (e.g. in Python, Java or Scratch) or realize any other idea! Just be creative! 😉

2. PRINTING IN 3D
   a. Make a research about 3D printing and answer the questions!
      i. How does it work? _____
      _____
      ii. For what use the people nowdays this technology? Find interesting ideas! _____
      _____
      _____
      iii. What is the future of this technology? What can we use it for in the Mars? _____
      _____
      _____
   b. Search the website *tinkercad.com*!
   c. Use the included shapes and design a house number plate! Be creative, maybe somebody in the future in the Mars will print this for his/her house! 😊
   d. *Additional task*. If you are brave, you can design a whole Mars-house also! (In the next task, you can collect some idea how should it look like!)

3. COLONIZE MARS!
   a. Design a city on the Mars! Make also a small research before starting! Some questions what maybe can help you:
      i. How should the homes look like? What is difference between the houses on the Earth and ont he Mars? What problems do we have to solve when we build a house on the Mars? Think about the Hab (*QR code*) where Mark lived in the movie!
      ii. What kind of institutions do we need on Mars? Are the different than in the Earth? For example how should a mall or a „gas station" look like?
   b. Make a digital poster about it! You can use any program you already knew or search for one on the internet!

Annex 3- English lesson

I. JOB ADVERTISEMENT (10 min)

NASA is highly satisfied with your achievements and wants to recruit more astronauts. Work in pairs or in threes and discuss the followings:

- the **field of science** you need (eg.:biology, chemistry etc.)
- what kind of scientist you would like to **recruit** (biologist, chemist etc.)
- what is going to be included in their job (write a short **description**: We are looking for candidates for the position of _____, who will be responsible for _____)
- decide on their **duties** (the new candidate will need to make research/report, give advice on ….etc.
- also define the **requirements** (The individual selected will be required to have the following skills/degree/documents etc.)
- What you can offer (bonus, trainings, projects, travelling etc.)

Write a job advertisement based on the following plan:

1. **Description**

   NASA is currently seeking interested candidates for the position of_____.
2. **Duties**

   The nominated astronaut will need to give expert advice on _____

   The individual selected will be responsible for _____
3. **Requirements**

   Candidates must possess expert knowledge in the field of _____ and have at least 3 years of specialized experience in _____. You must clearly state in your resume the following: _____

   Documents: Resume, diploma and other certifications
4. **What NASA can offer**

Display your Job Advertisement on to the Board!

II. CV (10 min)

Walk around the classroom, read the advertisements and choose one you would like to apply to.

Complete the following CV template and pin it on to the selected advertisement:

In the '*Objective*' field you need to give information about your professional background in short.

In the '*Key Strength'* field you need to give examples for the listed skills.

In the *'Education'* field you need to write where and how long you studied. eg.: 2018-2021 Princeton University, biology faculty

III JOB INTERVIEW (15 minutes)

Work in threes: one candidate and two employers. Make a job interview to decide who the best candidate is using the following questions:

- Can you tell us something about yourself?
- What do you see as your strength?
- In which area do you need to develop?
- What do you know about NASA?
- How do your skills and experience match the position?
- Where do you see yourself in 5 years?

The job interview should not be longer than **3 minutes per each candidate.**

The exercises are adapted from the following sources:

Cambridge English for Job Hunting, Colm Downes, Cambridge University Press, 2008

Gerilla CVs and other training materials, Barát András,2020

NASA Career webpage: https://www.nasa.gov/careers

Spider Man

COUNTRY: Lithuania

SCHOOL: Pakruojis „Atzalynas" Gymnasium

SUBJECTS/TEACHERS: Biology (Daiva Makauskienė)

Chemistry (Vita Gudonienė, Danutė Stočkūnienė)

Physics (Rasa Bertulienė)

Mathematics (Rita Vinskūnaitė).

Movie	Spider Man 2
Title	Spider Superpowers
Level	10-11
ICT support, equipment needed	PC's with Installed Jmol programme, laboratory equipment
Teaching aims	To learn more about spider biology After analysing the structure and properties of the protein, to model the spatial structure of the protein by using "Jmol"program/software After analysing the protein, get acquainted with its elastic deformations and determine the modulus of elasticity (Young's modulus) of the nylon thread. After analysing the structure of the spiders, the formation of the spider web, its structure and properties, to find out how long it would take for a spider or how many spiders should produce protein for the spider web that could stop a moving train.
Learning outcomes	Increased knowledge of spider biology, structure and properties of a spider web, modulus of elasticity, ability to solve mathematical problems. Increased creativity, artistic, cooperation skills
Methodologies/methods	Method „Experts" (the group of students participating in the project works in the classes/groups of each subject. The smaller groups are considered as experts of the material they are preparing with the guidance of a teacher. Later the prepared activities are organised for the entire project group – to the rest of the project team). Group work

Activity phases and timing	1. Web photography competition and exhibition 2. Activities on spider biology (I. Analysis of spider structure, spider web shapes and sizes, spider web formation, II. Microscopic examination of the structure, III. Crocheting a web of a nylon thread (Biology, Mathematics) – material to use Annex 1. 3. Analysis of web protein structure and properties. Polymer modeling by using "Jmol" programme – material to use Annex 2. 4. Degrading of spider's web protein - color reaction of cobweb protein with concentrated nitric acid (Chemistry, IT) – material to use Annex 3.[1] 5. Analysis of Young's modulus. Determination of elasticity and strength of a nylon webcob according to Young's modulus (Physics, Mathematics) – material to use Annexes 4, 5 and 5.1. 6. Determination of the dependence of the force (load) resistance on the size of the spider web using spider webs made of a nylon thread (Biology, Physics, Mathematics) – material to use Annex 6.[2] 7. Various mathematical calculations on the spider silk/thread thickness, web shape and size that can stop a moving train, based on spider web silk elasticity studies (Physics, Mathematics). Here you can find a video to use:  Material to use - document Annex 7.1 and Annex 7.2 This part is about development of mathematical reasoning and problems, fact analysis and problem solving (the topics to be covered: graphical representation of the dependence of one size on another, units of measurement and their enlargement and comminution, volumes of spatial figures, area of a circle, properties of numerical inequalities, inequalities, their systems,

[1] Activities 3 and 4 can be combined and organised as an activity of 2 parts.

[2] Activities 4 and 5 can be combined and organised as an activity of 2 parts.

	double inequalities, estimates, percentage, scale, proportion, expression of one variable in another). 8. Summary/evaluation and presentation of the project results.
Evaluation/Evaluation tool	Tool "Cobweb" (self-evaluation for students) Discussion and feedback sessions

To start the project with watching the afrementioned episode and the idea below.

While watching "Spider-Man 2" about Peter Parker, a guy who was bit by an irradiated spider and that gives him speed, reaction, strength, the ability to make and shoot sticky, durable spider web threads, one episode raised doubts about whether the creators were far from reality or there is some grain of truth. The episode is about the sudden appearance of the Spider-Man, who shoots silk threads and creates a spider web of incredibly solid material that stops an unstoppably flying train. "But what if?"

Links to the episodes of Spider Man 2:

- https://youtu.be/SCyg3hWNYVM - 9:09
- https://45.87.43.43/filmas/zmogus-voras-2-online/ - 1:38:32

Annex 1- Spider Biology

Activities – Biology

The following activities are organized:

Step I - Presentation and discussion of the facts of spider biology.

Step II - The examination of a cobweb under a microscope.

Step III - Crocheting a web of nylon thread on a wooden frame.

Below you can find the material to use for the activities.

I. Spider biology

Spiders - belong to arthropods, the class of arachnids. Their representatives have eight legs, no wings and are able to produce cobweb silk. These arthropods are found on all continents except Antarctica. In total, there are about 38,000 species.

Reproduction

Mating and copulation of each species are quite different and this is related to the behavioral characteristics of the spiders. Males are thought to be attracted to pheromones secreted by females, their cobwebs and, in part, purely optical stimuli. Even before fertilization, males perform complex ritual dances, drawing the attention of the predatory female so that they would not mistake males for prey. These dances are almost always associated with leg vibrations and rhythmic tummy tucking. The poses of copulating spiders are quite various and differ for each family or even close species. During copulation, the female often develops catalepsy (lease), which can last for different periods of time. After recovering from this condition, she in many cases attacks and eats the male. However, males of most species escape and do not always fall prey to females.

Spider silk

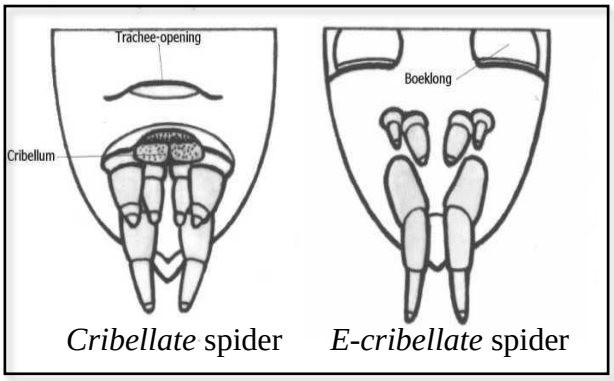
There are several glands located at the spider's abdomen, which produce the silken thread. Every gland produces a thread for a special purpose. There are seven different known glands. Each spider possesses only some of these glands and not all seven together. The glands known as:

- *Glandula Aggregata* – produces the sticky material for the threads.

- *Glandula Ampulleceae* – major and minor glands are used for the silk of the walking thread.
- *Glandula Pyriformes* – is used for the production of the attaching threads.
- *Glandula Aciniformes* – produces threads for the encapsulation of prey.
- *Glandula Tubiliformes* – produces thread for cocoons.
- *Glandula Coronatae* – is used for the production of the adhesive threads.

Normally a spider has three pairs of spinners, but there are spiders with just one pair or as many as four pairs. Every spinner has it own function. There are small tubes in the spinners, which are connected to the glands. The number of tubes varies between 2 and 50.000. In spider silk there are three substances that are important for its durability: pyrolidin, potassium hydrogen phosphate and potassium nitrate. Pyrolidins are very hygroscopic (binds water). This substance prevents the thread from drying out. Potassium hydrogen phosphate makes the thread acidic and prevents fungal and bacterial growth. A low pH causes denaturation (become insoluble) of proteins. Potassium nitrate prevents this and the proteins are salted which prevents bacterial and fungal growth.

By studying their threads two groups of spiders can be recognized, the *Cribellate* and the *E-cribellate* spiders. *Cribellate* spiders comb their silk to a woolly structure. To do this they have a comb (*calamistrum*) on the metatarsus or the tarsus of the fourth legs and an extra silk producing organ (*cribellum*) just in front of the spinners, which appears as a transparent plate. The comb pulls the



silk out of the *cribellum* and the silk is combed to a woolly structure. The combed silk is made up of thousands small threads enforced by some thicker ones. There is no glue on the threads but the insect gets stuck with the hairs on their body in the silk. The thicker threads in the silk prevent the insect from tearing the silk.

Spider web

There are glands in the abdomen of a spider that secrete a protein called spider silk, from which the spider web is made. Three simple forms of web can be recognized. The sheet web, the orb web and the spatial web.

The sheet web

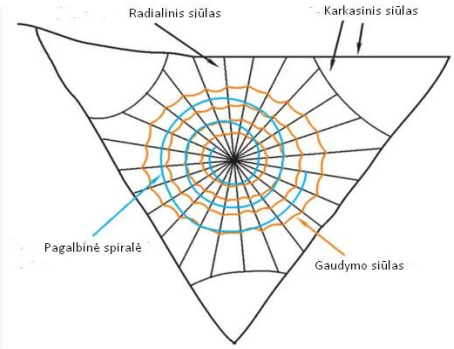
The orb web

The spatial web

The base of the net is very similar to a snowflake or a point from the center of which several rays differ. Sometimes a spider makes a base out of several threads at once, as if reinforcing its roads in advance.

When the base is ready, the animal begins to build "catching spirals".

The net used to catch the prey consists of several types of thread.

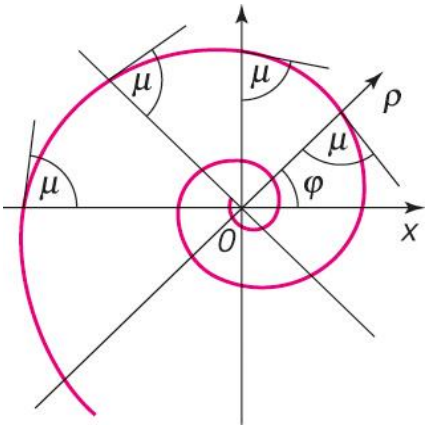


The structure of the cobweb consists of the outer lines of the frame or carcass, to which are attached radial (spoke-like) lines holding a helical shape of an adhesive thread which occupies most of the surface of the cobweb.

To create a circle-like trapping net, the spider *Araneus diadematus* first prepares a carcass from the radial threads. The spider then returns to the center and begins to make a temporary auxiliary spiral. The auxiliary spiral holds the structure together and serves as a spider path to build the capture spiral. The entire main frame of the net, including the beams, is made of non-stick thread, but a double thread covered with glue is used for the catching spiral. Surprisingly, these two spirals have different geometric shapes. The auxiliary spiral has relatively few turns and the distance between them increases each time. This happens because when laying it, the spider moves at the same angle

into the rays. The shape of the auxiliary spiral thus obtained is approximately described by a logarithmic spiral.

The adhesive trap spiral is designed on a different principle. The spider begins to move from the edge and moves towards the center, maintaining the same distance between turns, thus obtaining a spiral that can be described as the spiral of Archimedes. At the same time, it eats the threads of the auxiliary spiral.



The different types of nets vary in size, number of rays, density of trapping thread, width of the free zone, and so on. Some of the tribes of this family live semi-social lives and form colonies of thousands of individuals whose cobwebs are interconnected, such as the *Araneus sclopetaria* common in Eastern Europe. *Metepiera* spiders living in Mexico even make the nets together.

This video shows the building of a section of the sticky spiral in *Araneus diadematus*.

Not only traps are woven from silk, but also hiding places, "nests", and with its help spiders travel downwind and thus spread to new places.

Lifeline

Spiders like the jumping spider, the lynx spider, the crab spider and many others do not use webs to catch prey. They use their eyes and speed to catch insects. The above-mentioned spiders use their silk as a lifeline. While moving they release a thread that is attached to a secure spot. If they accidently fall down the lifeline makes it possible to return to their original position.

Cocoons

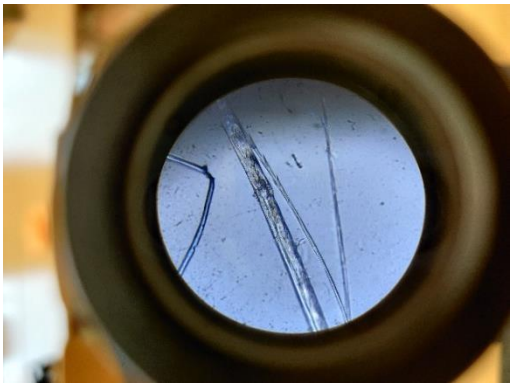
Fertilized females begin to lay eggs after about 2-6 weeks. A special cobweb gland produces a cobweb material that is used for egg cocoon. Most spider cocoons contain dozens of eggs, and some tarantulas can have as many as 300-700.

Spiders in Lithuania

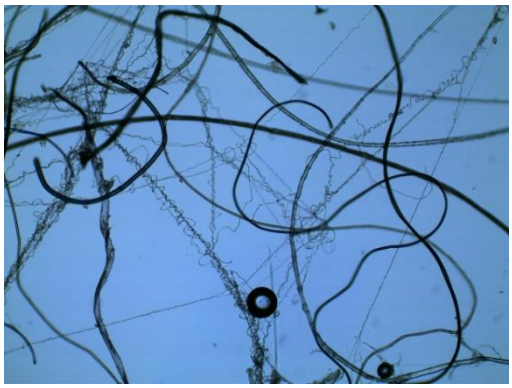
Lithuania's most abundant family of spiders - hammers knit double nets. Some of them build quite small, irregular traps that catch small ticks, aphids, mosquitoes or flies. Other members of this family make flat, slightly convex, hammock-like nets between the grass, in the hollows of the soil,

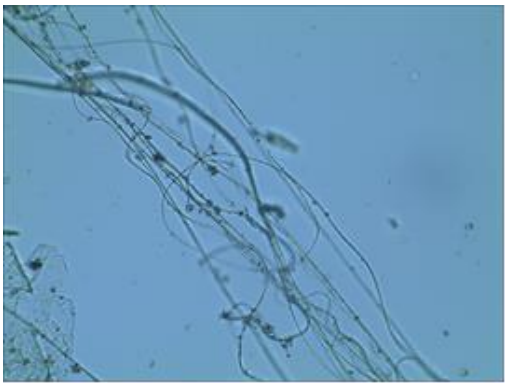
on the branches of trees and shrubs. Above the net, it stretches vertically thin invisible threads. Flying insects collide with them and fall into a densely twisted trap, become entangled in threads and become a light prey to a spider. The spider usually hangs its back down, in this position it is barely noticeable, as the dark underside merges with the background of the soil and branches, and the upper, light, hardly noticeable against the background of the blue sky. Few tangled insects in the web can resist this seemingly tiny spider. The more often ants are able to escape from these cobwebs. Young hammers spread well with the help of their cobwebs, which, carried by a gust of wind, resemble a tiny white flying cloud. In this way, these spiders can significantly expand their populated area.

II. The examination of a cobweb under a microscope

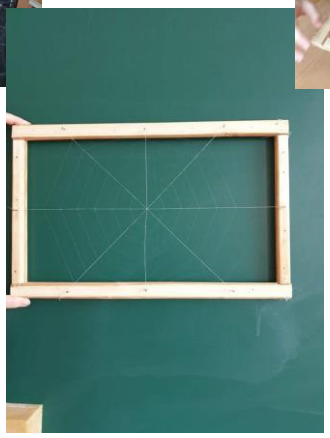


While learning about spider biology you can examine the structure of the cobwebs under a microscope.





III. Crocheting a cobweb made of nylon thread



Annex 2- Analysis and imaging of Protein structure by Jmol programme

Aim of the activity

To construct and see the molecule of the protein that makes up the spider web by using Jmol programme

The activity organisation steps

1. **Installation and launch of the Jmol programme**

Jmol is a free, open-source programme for molecular imaging that anyone can use, from high school students to researchers. Jmol runs on the Java platform. Therefore, you should first install Java on your computer if it is not already available.

You can download Java from here.

You can download Jmol from here by choosing *Download Latest Version*.

After downloading the zip archive, it needs to be unzipped and can be used. No additional installation is required.

Launch the program by double-clicking the Jmol.jar file (folder: jmol-14.29.31). If you have just installed Java, the system may not recognize the file. In this case, you need to restart your computer. It is recommended that you make a shortcut to this file, place it in a convenient and easily accessible location, and use it to launch the program.

In the window that opens, right-click and select *Console* from the opened table. The program is ready for use.

2. **Explanation to the students that a spider web is a protein molecule, consisting of different amino acids and asking the students to search for the information on what amino acids make up spider web protein molecule.**

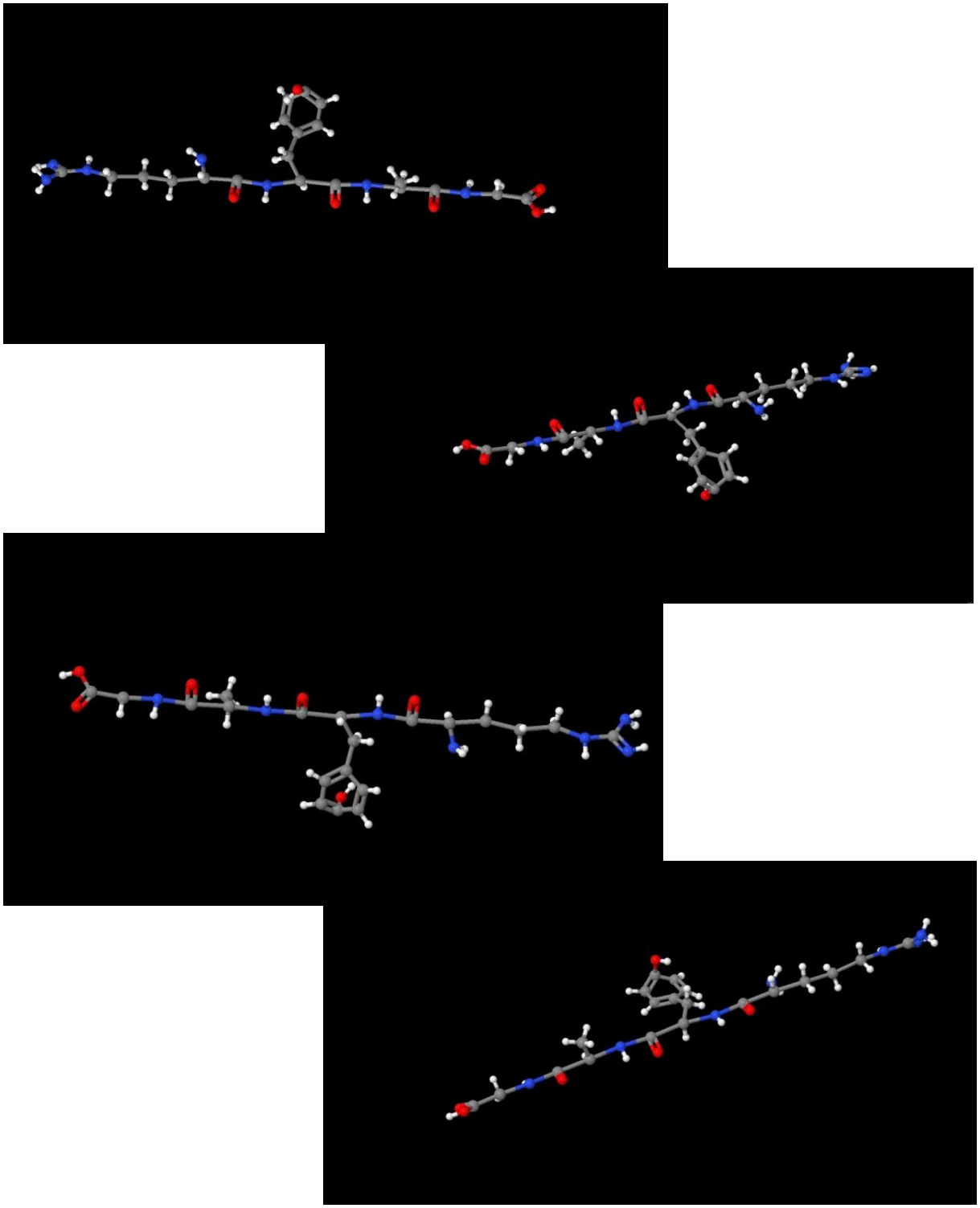
The repetitive chain of a spider web protein is composed of glycine, alanine, tyrosine, and arginine molecules linked by peptide bonds (Gly-Ala-Tyr-Arg).

3. **Finding the molecules of glycine, alanine, tyrosine, and arginine on the jmol programme and connecting them.**

Students will see molecule of the spider web on the screen and will be able to have its spatial structure.

4. **Asking students which amino acids give density to the spider web protein and which are responsible for the elasticity.**

Glycine and alanine give density to the spider web protein, and tyrosine and arginine give elasticity.



Prepared by Vita Gudonienė, teacher of Chemistry at Pakruojis ,,Atžalynas“ Gymnasium

Annex 3 - Degrading of spider's web protein

Protein color recognition reaction of web threads

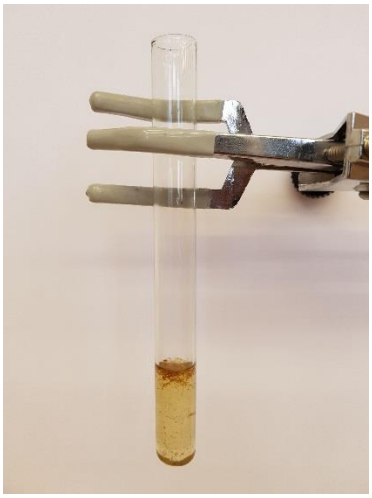
Cobweb thread is a protein consisting of amino acids.

Aim of the experiment is to investigate whether protein contains amino acids containing a benzene ring.

Workflow

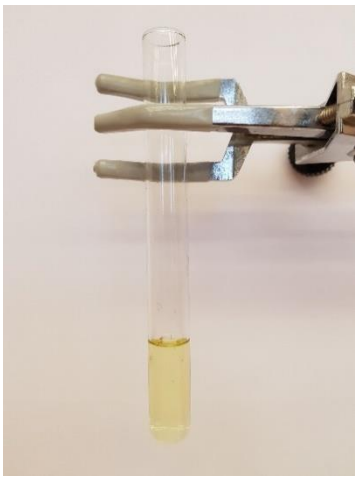
You need to put the spider webs into a test tube, pour them with a concentrated nitric acid and heat them. You are supposed to monitor color change.

Illustrations and explanations to the students



Picture 1

Before the experiment



Picture 2

After the experiment

If the solution turns yellow after reaction it means that the web contains amino acids containing a benzene ring.

Annex 4 - Introduction to Maths and Physics activities

Can a spider silk thread stop a train?

Using our imagination and thickening the silk thread a little more than a thousand times, we could get a silk thread as strong as in the movie *The Spider-Man*. Still unbelievable that spider silk can be so strong? That's fine. Using science, articles on the findings and hypotheses of research conducted by scientists, let us examine whether it is really possible.

Discoveries and insights of Leicester students and other scholars

We chose an episode, where Spider- Man stops an incredibly fast and massive train using only his spider webs. As it turned out, the spider silk threads, which the spider webs are made of, in the film had to withstand a force of 300,000 N (Newtons).

To further clear up the strength of silk to withstand such a monstrous force, the scientists used a physical model and described the strength of the spider silk thread through the Young modulus. The Young modulus, measured in Pascals (tensile or compressive force per square meter), indicates how much force will be required to double the tensile material.

What should Young's modulus be, so the spider silk only stretches twice under a force of 300 kN? According to calculations, the Young's modulus should be 3,100,000,000 Pa or 3.1 Gigapascals (GPa). By comparison, that's more than 30,5 thousand times the force of atmospheric pressure, which is 101 325 Pa (0,101325) GPa). Is that even possible? Having examined the strongest spider silk of Young modulus worth were shocking. The spider silk, used on the Hollywood scene, was supposed to have a Young modulus of around 3.1 GPa, which is already a massive number. Further studies show that the modulus of the silk thread used in testing ranged from 1.5GPa to 12GPa! That`s unbelievable, but the strongest existing spider silk on earth would extend to a twice longer length which would stop even a bigger train!

If the diameter of the thread is 1 mm, it can withstand a load of about 200 kg. Steel wire of the same diameter, for example, can withstand significantly less: 30-100 kg, depending on the type of steel. So why does the spider web have such unique features?

Spider silks are very thin, about 5 micrometres thick. That is about three times thinner than a human hair. But in reality, under favourable biological conditions, a strand 0.005 mm thick and 4 cm long can withstand a mass of up to 100 mg. Thicken this thread to 1 mm and it will hold 5 kg. Bread a thread that is 2cm in diameter from such threads and it will hold 2 tons! The entire web

can be up to 45 meters long and 2-4 micrometers thick. The thinnest thread of spider silk is more resistant to tension than a steel wire of appropriate thickness. It is said that an elastic, strong 1 mm diameter thread can hold up to 250 kilograms.

When testing the impact resistance of materials, three main properties are taken into consideration: resistance to tearing, resistance to tension and density. Tests have shown that to stretch a spider silk thread requires as much as 1.3 GPa of force. It has also been found that a silk thread of the same mass but thicker is much more resistant to tension than steel.

The most fracture-resistant silk is said to be produced by Darwin's bark spider (*Caerostris Darwini*), which has a fracture toughness of 520 J/cm^3. The spider was discovered in Madagascar in the Andasibe-Mantadia National Park in 2009. Its silk is the toughest biological material ever studied. Its tensile strength is 1.6 GPa.

The strength of the web is inversely proportional to the number of ripped threads

Scientists have figured out why cobwebs are able to withstand relatively enormous forces. The study revealed that the strength of cobwebs is determined not only by the exceptional properties of the threads, but also by the complex design of the web, which increases the strength of the entire knit. Due to the complex structure of the spiderweb, the overall strength of the web is not reduced but even increased when one thread is ripped. Markus Buehler from Massachusetts Institute of Technology, co-author of the research report, said: "The real force of a web lies not in the threads, but in the way in which the mechanical properties of the web change with different forces. It is a very clever feature of cobwebs that can be used in a wide range of areas of life to control minor breaches". Creating a typical cobweb consumes a lot of spider's energy - so there are many different "improvements" to the cobweb that prevent spiders from having to re-knit the entire web after more serious damage. Scientists have found that spider silk itself has the ability to soften or harden under different forces - unlike any man-made material. Comparative tests with other materials, from which similar webs have been twisted, have shown that spider silk is six times more resistant to damage caused by falling twigs or strong winds. When comparing the webs' resistance to weight, only one thread was ripped - so the spider could simply rebuild the broken thread instead of knitting the entire spider web once again. By removing up to 10 percent of all threads from different locations on the web, the web didn't become weaker, but surprisingly got up to 10 percent stronger.

Spider silk against steel, nylon, etc. substances

The strength of a material is measured in units called dernier (1 dernier = 1g/9000m). The strength of spider threads is 5 to 8 dernier. From materials known to humans, only glass and nylon have similar properties. Known for its strength, steel is only 3 dernier.

In terms of its physical properties, cobweb silk is very close to good quality nylon and one gram of cobweb silk can be stretched into a 70 km long continuous yarn. The spider web's silk thread breaks at the length of 70 km, nylon 50-80 km, steel 35 km. The elasticity of the spider web is even more impressive. If steel can be stretched up to 8%, nylon to 15 - 30%, then the spider web of a European garden spider (*Araneus diadematus) o*nly tears when it is stretched 30-40% from its original length.

How thick should a spider silk thread be to stop a Boeing-747 in full flight? (xs4all.nl)

Spider silk is also welcomed in the military industry to replace Kevlrar vests. In one study, 'silk skin' was created by combining spider silk with skin. Such a fabric has stopped a 9 mm bullet without any cracking, and according to the authors of the study, the possibilities are even greater by increasing the thickness of such fabric ten times.

Professor Pugno said: "We have found that the strong silk produced by spiders has a breaking strength of up to 5.4 gigapascals (GPa) and a modulus of thickness of up to 1570 Joules per gram (J/g). In comparison, the normal breaking strength of spider silk is about 1.5 GPa and the modulus of thickness is about 150 J/g.

Annex 5 - Young modulus of elasticity

Practical work
Determination of the Young's modulus of elasticity of a nylon thread

The aim of the work: to determine the Young's modulus of elasticity of a nylon thread.
Work tools: frame, stand, nylon thread, ruler, micrometer, weight holder, weights.
Workflow:

1. Measure the length of the thread with a ruler and calculate its average values. Repeat the test 3 times with 1 thread, 3 threads and 5 threads. Write the measurement results in Table 1.

Table 1

Number of threads	l, m
1	
3	
5	

2. Attach the measured thread to the different stand holders. Mark the middle of the thread where you will hang the weights. Bring the micrometer close to the center of the thread so that it touches the thread but does not deform it. Write the initial micrometer display value d_0.

$d_{0=}$

3. Hang the weights of the known mass one by one on the thread and write the displayed values each time of the micrometer in Table 2.

Table 2

Experiment No.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 thread																
Weight mass, kg	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1	1,1	1,2	1,3	1,4	1,5
Micrometer displayed values (with weight), m	d_0	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}	d_{12}	d_{13}	d_{14}	d_{15}
Thread displacement, m	h_0	h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8	h_9	h_{10}	h_{11}	h_{12}	h_{13}	h_{14}	h_{15}
3 threads																
Weight mass, kg	0	0,2	0,4	0,6	0,8	1,0	1,2	1,4	1,6	1,8	2,0	2,2	2,4	2,6	2,8	3,0
Micrometer displayed values (with weight), m	d_0	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}	d_{12}	d_{13}	d_{14}	d_{15}
Thread displacement, m	h_0	h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8	h_9	h_{10}	h_{11}	h_{12}	h_{13}	h_{14}	h_{15}
5 threads																
Weight mass, kg	0	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0	6,0	6,5	7,0
	d_0	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}	d_{12}	d_{13}	d_{14}	d_{15}

Micrometer displayed values (with weight), m																
Thread displacement, m	h_0	h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8	h_9	h_{10}	h_{11}	h_{12}	h_{13}	h_{14}	h_{15}

4. Calculate the elongation values of the nylon thread from the formulas and write them in Table 3.

$$x_1 = 2\sqrt{\left(\frac{l}{2}\right)^2 + {h_1}^2}, \dots, x_{15} = 2\sqrt{\left(\frac{l}{2}\right)^2 + {h_{15}}^2}.$$

Table 3

1 thread															
Nylon thread elongation, m	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}
3 threads															
Nylon thread elongation, m	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}
5 threads															
Nylon thread elongation, m	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}

5. Calculate the strain force $F_1 = m_1 g, \dots, F_{15} = m_{15} g$, g – free fall acceleration, g = 9,8 m/s^2, stiffness coefficient $k_1 = \frac{F_1}{x_1}, \dots, k_{15} = \frac{F_{15}}{x_{15}}$ and its average value quid according to the formulas. Write the results in Table 4.

Table 4

Nylon thread number	Deformation force, N		Stiffness coefficient, $\frac{N}{m}$		The average value of the stiffness coefficient, $\frac{N}{m}$
1	F_1		k_1		
	F_2		k_2		
	F_3		k_3		
	F_4		k_4		
	F_5		k_5		
	F_6		k_6		
	F_7		k_7		
	F_8		k_8		
	F_9		k_9		
	F_{10}		k_{10}		
	F_{11}		k_{11}		
	F_{12}		k_{12}		

	F_{13}		k_{13}		
	F_{14}		k_{14}		
	F_{15}		k_{15}		
3	F_1		k_1		
	F_2		k_2		
	F_3		k_3		
	F_4		k_4		
	F_5		k_5		
	F_6		k_6		
	F_7		k_7		
	F_8		k_8		
	F_9		k_9		
	F_{10}		k_{10}		
	F_{11}		k_{11}		
	F_{12}		k_{12}		
	F_{13}		k_{13}		
	F_{14}		k_{14}		
	F_{15}		k_{15}		
5	F_1		k_1		
	F_2		k_2		
	F_3		k_3		
	F_4		k_4		
	F_5		k_5		
	F_6		k_6		
	F_7		k_7		
	F_8		k_8		
	F_9		k_9		
	F_{10}		k_{10}		
	F_{11}		k_{11}		
	F_{12}		k_{12}		
	F_{13}		k_{13}		
	F_{14}		k_{14}		
	F_{15}		k_{15}		

6. Using the formulas $S_1 = \frac{\pi d_1^2}{4}, \dots, S_{15} = \frac{\pi d_{15}^2}{4}$ ir $E_1 = \frac{F_1 x_1}{S_1 \Delta x_1}, \dots, E_{15} = \frac{F_{15} x_{15}}{S_{15} \Delta x_{15}}, \Delta x_1 = x_1 - l, \dots, \Delta x_{15} = x_{15} - l$ calculate the cross-sectional area of the nylon thread and the Young's modulus of elasticity, its average value and write them in Table 5.

Table 5

Nylon thread number	Nylon thread area, m^2		Young's modulus of elasticity, $\frac{N}{m^2}$		The average value of the Young's modulus of elasticity, $\frac{N}{m^2}$
1	S_1		E_1		
	S_2		E_2		
	S_3		E_3		
	S_4		E_4		
	S_5		E_5		
	S_6		E_6		
	S_7		E_7		
	S_8		E_8		

	S_9		E_9		
	S_{10}		E_{10}		
	S_{11}		E_{11}		
	S_{12}		E_{12}		
	S_{13}		E_{13}		
	S_{14}		E_{14}		
	S_{15}		E_{15}		
3	S_1		E_1		
	S_2		E_2		
	S_3		E_3		
	S_4		E_4		
	S_5		E_5		
	S_6		E_6		
	S_7		E_7		
	S_8		E_8		
	S_9		E_9		
	S_{10}		E_{10}		
	S_{11}		E_{11}		
	S_{12}		E_{12}		
	S_{13}		E_{13}		
	S_{14}		E_{14}		
	S_{15}		E_{15}		
5	S_1		E_1		
	S_2		E_2		
	S_3		E_3		
	S_4		E_4		
	S_5		E_5		
	S_6		E_6		
	S_7		E_7		
	S_8		E_8		
	S_9		E_9		
	S_{10}		E_{10}		
	S_{11}		E_{11}		
	S_{12}		E_{12}		
	S_{13}		E_{13}		
	S_{14}		E_{14}		
	S_{15}		E_{15}		

7. Compare the values obtained with the values from Table 6

Table 6

Material	Modulus of elasticity E, N/m^2
Wood (oak)	$(9,1 \div 11,8) \cdot 10^{10}$
Steel	$2,059 \cdot 10^{11}$
Steel	$2,063 \cdot 10^{11}$
Steel	$2,171 \cdot 10^{11}$
Steel	$2,204 \cdot 10^{11}$
Steel	$2,111 \cdot 10^{11}$
Aluminum	$6,7 \cdot 10^{10}$
Brass	$9,2 \cdot 10^{10}$
Copper	$11,2 \cdot 10^{10}$

Lead	$1{,}6 \cdot 10^{10}$
Constant	$16{,}3 \cdot 10^{10}$

8. For each nylon thread, draw the dependence of the elongation of the thread on the deformation force $x = f(F)$.

9. Summarize the results and write the conclusions.

Annex 5.1 - Answer sheet_Young modulus of elasticity

Practical work

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Work tools: frame, stand, nylon thread, ruler, micrometer, weight holder, weights.

Workflow:

1. Measure the length of the thread with a ruler and calculate its average values. Repeat the test 3 times with 1 thread, 3 threads and 5 threads. Write the measurement results in Table 1.

Table 1

Number of threads	l, m
1	0,508(3)
3	0,508(3)
5	0,509

2. Attach the measured thread to the different stand holders. Mark the middle of the thread where you will hang the weights. Bring the micrometer close to the center of the thread so that it touches the thread but does not deform it. Write the initial micrometer display value d_0.

d_0= 0,00014 m

3. Hang the weights of the known mass one by one on the thread and write the displayed values each time of the micrometer in Table 2.

Table 2

Experiment No.	0	1	2	3	4	5	6	7	8	9	10	11
1 thread												
Weight mass, kg	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1	1,1
Micrometer displayed values (with weight), m	d_0	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}
	0,00014	0,00014	0,00014	0,00013	0,00012	0,00011	0,00011					
Thread displacement, m	h_0	h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8	h_9	h_{10}	h_{11}
	0	0,092	0,103	0,122	0,149	0,185	0,246					
3 threads												
Weight mass, kg	0	0,2	0,4	0,6	0,8	1,0	1,2	1,4	1,6	1,8	2,0	2,2
Micrometer displayed values (with weight), m	d_0	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}
	0,00015	0,00014	0,00014	0,00014	0,00013	0,00012	0,00012	0,00012	0,00011	0,0001	0,00009	0,00008
Thread displacement, m	h_0	h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8	h_9	h_{10}	h_{11}
	0	0,065	0,09	0,122	0,145	0,145	0,156	0,163	0,168	0,172	0,176	0,182
5 threads												
Weight mass, kg	0	0,5	1,0	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5
	d_0	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}

Micrometer displayed values (with weight), m	0,00017	0,00016	0,00013	0,00012	0,00011	0,0001	0,00009	0,00009				
Thread displacement, m	h_0	h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8	h_9	h_{10}	h_{11}
	0	0,009	0,115	0,13	0,144	0,154	0,164	0,175				

4. Calculate the elongation values of the nylon thread according to the formulas and write them in Table 3.

$$x_1 = 2\sqrt{\left(\frac{l}{2}\right)^2 + {h_1}^2}, \dots, x_{15} = 2\sqrt{\left(\frac{l}{2}\right)^2 + {h_{15}}^2}$$

Table 3

1 thread											
Nylon thread elongation, m	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
	0,540	0,548	0,564	0,589	0,628	0,707					
3 threads											
Nylon thread elongation, m	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
	0,524	0,539	0,564	0,585	0,585	0,596	0,604	0,609	0,614	0,618	0,625
5 threads											
Nylon thread elongation, m	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
	0,509	0,559	0,572	0,585	0,595	0,606	0,618				

5. Calculate the strain force $F_1 = m_1 g, \dots, F_{15} = m_{15} g$, g – free fall acceleration, g = 9,8 m/s^2, stiffness coefficient $k_1 = \frac{F_1}{x_1}, \dots, k_{15} = \frac{F_{15}}{x_{15}}$ and its average value quid according to the formulas. Write the results in Table 4.

Table 4

Nylon thread number	Deformation force, N		Stiffness coefficient, $\frac{N}{m}$		The average value of the stiffness coefficient, $\frac{N}{m}$
1	F_1	0,196	k_1	1,814	5,563
	F_2	1,96	k_2	3,577	
	F_3	2,94	k_3	5,213	
	F_4	3,92	k_4	6,655	
	F_5	4,9	k_5	7,803	
	F_6	5,88	k_6	8,317	
	F_7		k_7		
	F_8		k_8		
	F_9		k_9		
	F_{10}		k_{10}		
	F_{11}		k_{11}		
3	F_1	1,96	k_1	3,740	19,521
	F_2	3,92	k_2	7,273	
	F_3	5,88	k_3	10,426	
	F_4	7,84	k_4	13,402	
	F_5	9,8	k_5	16,752	
	F_6	11,76	k_6	19,732	
	F_7	13,72	k_7	22,715	
	F_8	15,68	k_8	25,747	

	F_9	17,64	k_9	28,730	
	F_{10}	19,6	k_{10}	31,715	
	F_{11}	21,56	k_{11}	34,496	
5	F_1	4,9	k_1	9,627	33,079
	F_2	9,8	k_2	17,581	
	F_3	14,7	k_3	25,699	
	F_4	19,6	k_4	33,504	
	F_5	24,5	k_5	41,176	
	F_6	29,4	k_6	48,515	
	F_7	34,3	k_7	55,502	
	F_8		k_8		
	F_9		k_9		
	F_{10}		k_{10}		
	F_{11}		k_{11}		

6. Using the formulas $S_1 = \frac{\pi d_1^2}{4}, \dots, S_{15} = \frac{\pi d_{15}^2}{4}$ ir $E_1 = \frac{F_1 x_1}{S_1 \Delta x_1}, \dots, E_{15} = \frac{F_{15} x_{15}}{S_{15} \Delta x_{15}}$, $\Delta x_1 = x_1 - l, \dots, \Delta x_{15} = x_{15} - l$ calculate the cross-sectional area of the nylon thread and the Young's modulus of elasticity, its average value and write them in Table 5.

Table 5

Nylon thread number	Nylon thread area, m^2		Young's modulus of elasticity, GPa		The average value of the Young's modulus of elasticity, $\frac{N}{m^2}$
1	S_1	$1.54*10^{-8}$	E_1	0.2	$25.416*10^6$
	S_2	$1.54*10^{-8}$	E_2	1.62	
	S_3	$1.33*10^{-8}$	E_3	2	
	S_4	$1.13*10^{-8}$	E_4	2.18	
	S_5	$0.95*10^{-8}$	E_5	2.18	
	S_6	$0.95*10^{-8}$	E_6	1.58	
	S_7		E_7		
	S_8		E_8		
	S_9		E_9		
	S_{10}		E_{10}		
	S_{11}		E_{11}		
3	S_1	$1.54*10^{-8}$	E_1	4.04	$88.94*10^6$
	S_2	$1.54*10^{-8}$	E_2	4.17	
	S_3	$1.54*10^{-8}$	E_3	3.46	
	S_4	$1.33*10^{-8}$	E_4	3.89	
	S_5	$1.13*10^{-8}$	E_5	5.72	
	S_6	$1.13*10^{-8}$	E_6	6	
	S_7	$1.13*10^{-8}$	E_7	6.42	
	S_8	$0.95*10^{-8}$	E_8	8.3	
	S_9	$0.79*10^{-8}$	^{0E9}	10.7	
	S_{10}	$0.64*10^{-8}$	E_{10}	14.14	
	S_{11}	$0.5*10^{-8}$	E_{11}	18.72	
5	S_1	$2.01*10^{-8}$	E_1	-	$137.053*10^6$
	S_2	$1.33*10^{-8}$	E_2	7.5	
	S_3	$1.13*10^{-8}$	E_3	10.51	
	S_4	$0.95*10^{-8}$	E_4	13.82	
	S_5	$0.79*10^{-8}$	E_5	18.36	
	S_6	$0.64*10^{-8}$	E_6	24.11	
	S_7	$0.64*10^{-8}$	E_7	25.03	
	S_8		E_8		
	S_9		E_9		
	S_{10}		E_{10}		
	S_{11}		E_{11}		

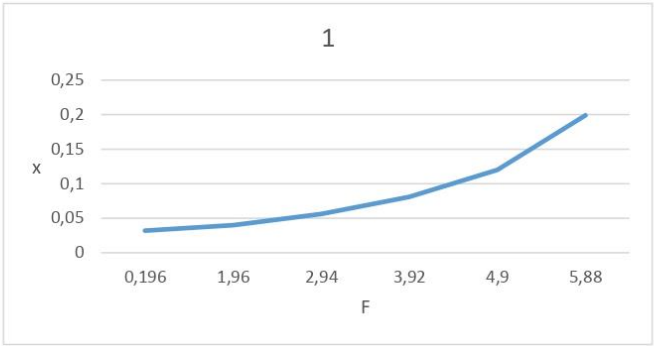
7. Compare the values obtained with the values from Table 6.

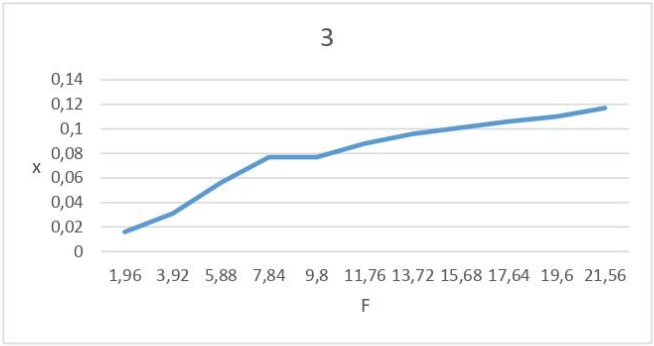
Table 6

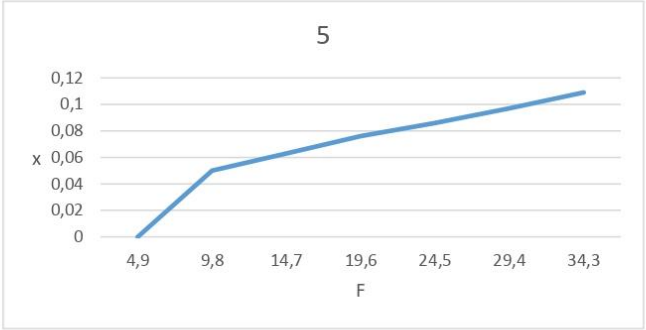
Material	Modulus of elasticity E, N/m^2
Wood (oak)	$(9,1 \div 11,8) \cdot 10^{10}$
Steel	$2,059 \cdot 10^{11}$
Steel	$2,063 \cdot 10^{11}$
Steel	$2,171 \cdot 10^{11}$
Steel	$2,204 \cdot 10^{11}$
Steel	$2,111 \cdot 10^{11}$
Aluminum	$6,7 \cdot 10^{10}$
Brass	$9,2 \cdot 10^{10}$
Copper	$11,2 \cdot 10^{10}$
Lead	$1,6 \cdot 10^{10}$
Constant	$16,3 \cdot 10^{10}$

Young's modulus of elasticity of nylon thread is smaller than that of the other materials in Table 6 (oak wood, steel, aluminium, brass, copper, lead). This means, that nylon can be stretched more than the other materials.

8. For each nylon thread, draw the dependence of the elongation of the thread on the deformation force x = f(F).







9. Summarize the results and write the conclusions.

   Young's modulus of elasticity of nylon thread is smaller than that of the other materials in Table 6 (oak wood, steel, aluminium, brass, copper, lead). This means, that nylon can be stretched more than the other materials.

   Threads together can hold more mass than the sum of individual threads can. One thread can hold up to 0,6 kilos and five threads hold 3,5 kilos (0,6×5=3, which is less than 3,5 kg).

   The more threads, the smaller the elasticity. 5 threads stretch up to 21,41%, meanwhile 1 thread - up to 39,17%.

   The more threads, the larger deformation force it can whitstand.

   The more threads, the larger is the stiffness koeficient.

Annex 6 - Cobweb load maintenance

Practical work

Cobweb load maintenance observation

The aim of the work: Find out what load the cobwebs hold.

Work tools: table or stands, mounting brackets, 3 frames with cobwebs, ruler, micrometer, holder to hang weights, weights.

Workflow:

1. Attach the cobweb frame No. 1 to the table or stands.
2. Hang the weights in the middle of the cobweb and observe the maximum mass the cobweb can hold until it breaks.
3. Using the formula $F = mg$, calculate the load force at $g = 9.8$ m / s^2.
4. Repeat the experiment 3 times with 1 thread, 3 threads and 5 threads. Write the measurement results in Table 1.

Table 1

Number of threads	m, kg	F, N
1		
3		
5		

5. Repeat the experiment according to steps 1-4 with cobweb No. 2. Write the measurement results in Table 2.

Table 2

Number of threads	m, kg	F, N
1		
3		
5		

6. Repeat the experiment according to steps 1-4 with cobweb No. 3. Write the measurement results in Table 3.

Table 3

Number of threads	m, kg	F, N
1		
3		
5		

7. Summarize the results and write the conclusions.

Annex 7.1 - Mathematical considerations

The scientists found that spider threads:

- tension (elasticity, deformation) is 20 - 40%,
- density - 1.3 g / cm^3,
- strength - 1.5 - 12 GPa.

The strength (fracture resistance) is calculated according to the formula:

$$E = \frac{F \cdot l}{S \cdot \Delta l}$$

(*F is the force N / m^2, l is the initial length of the material, S is the cross-sectional area of the material, Δl is the elongation of the initial length*).

Students at the University of Leicester, after examining whether Spider-Man could actually stop the train, calculated:

- The strength of the thread fired by a spider is 3.12 GPa when it is doubled,
- A force of 300,000 N generated by a 4-wagon underground train stalling at a speed of 24 m/s with 984 people in it.

Sources state that the thickness of the thread in the film is about 1 cm. It means that, the strength of the thread in the film may be:

$$E = \frac{300000}{25 \cdot 10^{-6} \pi} = 3{,}8 \text{ GPa.}$$

Task 1: What is the thickness of the Spider-Man thread according to the thread strength determined by the students of the University of Leicester?

Solution:

$$3{,}12 \cdot 10^9 = \frac{300000}{\pi \cdot r^2}$$

$$r^2 = \frac{300000}{\pi \cdot 3{,}12 \cdot 10^9}$$

$$r \approx 0{,}00553 \text{ mm} = 0{,}553 \text{ cm}$$

The thickness of the spider-man's thread in the film should be around 1.1 cm.
In the first attempt in the film, the Spider-Man failed to stop the train and the thread did not break, the walls of the buildings did not withstand that force. In the second attempt, 8 threads were fired at different times. We assume that a force of 300,000 N was distributed over those 8 threads.

Task 2: How thick should be Spider-Man's thread, to withstand a force of 37500 N when it stretches twice and its strength is $E \in [1.5; 12]$ GPa?

Solutions:

$$1{,}5 \cdot 10^9 \leq E \leq 12 \cdot 10^9$$

$$\frac{1}{12 \cdot 10^9} \leq \frac{1}{E} \leq \frac{2}{3 \cdot 10^9}$$

$$\frac{37500}{\pi \cdot 12 \cdot 10^9} \leq r^2 \leq \frac{2 \cdot 37500}{\pi \cdot 3 \cdot 10^9}$$

$$0{,}997 \leq r \leq 2{,}82\ (mm)$$

$$1{,}99 \leq d \leq 5{,}64\ (mm).$$

Task 3: What can be the strength of a 1 cm thick spider thread?

Solution:

$$E = \frac{300000}{25\pi \cdot 10^{-6} \cdot 0{,}4} \approx 9549.296 \cdot 10^6 \approx 9{,}5 \cdot 10^9 \text{ GPa}.$$

Task 4: What thickness spider thread could withstand a force of 37500 N when its deformation is 40% and the strength is $E \in [1,5; 12]$ GPa?

Solution:

$$1{,}5 \cdot 10^9 \leq E \leq 12 \cdot 10^9$$

$$\frac{1}{12 \cdot 10^9} \leq \frac{1}{E} \leq \frac{2}{3 \cdot 10^9}$$

$$\frac{37500}{\pi \cdot 12 \cdot 10^9 \cdot 0{,}4} \leq r^2 \leq \frac{2 \cdot 37500}{\pi \cdot 3 \cdot 10^9 \cdot 0{,}4}$$

$$1{,}5 \leq r \leq 8{,}54\ (mm)$$

$$0{,}3 \leq d \leq 1{,}708\ (cm).$$

The strength formula shows that the higher the elasticity, the lower the strength, and the higher the elasticity, the higher the resistance.

Let's assess the strength that the Spider Man and the spider threads could withstand.

$$F = E \cdot \pi \cdot r^2 \cdot \frac{\Delta l}{l}.$$

Task 5: What force can a 1 cm thick Spider-Man and spider thread withstand at $E \in [1.5; 12]$ GP?

Solution:

In the case of the spider-man, when the thread is stretched double the length:

$$1{,}5 \cdot 10^9 \leq E \leq 12 \cdot 10^9,$$

$$1{,}5 \cdot 10^9 \leq \frac{F}{25 \cdot 10^{-6}\pi} \leq 12 \cdot 10^9,$$

$$117809{,}72 \leq F \leq 942477{,}79\ (N).$$

In the case of a spider, when the thread is stretched 40%:

$$1{,}5 \cdot 10^9 \leq E \leq 12 \cdot 10^9,$$

$$1{,}5 \cdot 10^9 \leq \frac{F}{25 \cdot 10^{-6}\pi \cdot 0{,}4} \leq 12 \cdot 10^9,$$

$$47123{,}88 \leq F \leq 376991{,}11\ (N).$$

So, the claim of a Singaporean scientist that the spider-man's thread in the film is underestimated could be confirmed.

Gravity, uneven braking when firing threads at different times is not taken into account in calculations.

Annex 7.2 – Mathematical tasks

Physics students at the University of Leicester reported in the "Journal of Physics Special Topics" that they had found out the power that might have been created by a massive, high-speed train which was stopped by Spider-Man in the movie. They established that the spider silk threads in the movie had to withstand a force of 300,000 N (Newtons). In explaining the strength of silk to withstand such a monstrous force, they used a physical model and described the strength of silk through the Young's modulus. The Young's modulus, measured in Pascals (tensile or compressive force per square meter), indicates how much force will be required to elongate the stretched material by a certain percentage from the initial length. According to their calculations, the Young's modulus should be 3,120,000,000 Pa or 3.12 GPa to double the length of the Spider-mans thread. Young's modules of the strongest spider silks studied, range between 1.5GPa - 12GPa!

In terms of its physical properties, cobweb silk is very close to good quality nylon and one gram of cobweb silk mass can be stretched into a 70 km long continuous yarn. In other words, each hanging thread of any material of a certain length begins to weigh so much that it breaks from its own weight. The spider web silk breaks at a distance of 70 km, nylon 50-80, steel 335 km. The elasticity of the spider web is even more impressive. If the steel can be stretched by 8% and nylon by 20%, then the thread of *Angulate Orbweavers* only breaks by stretching it 30-40% from its original length. It is estimated that the average length of a spider's web to create a net is 25 to 45 m.

Task 1. How thick should a thread be, to be able to hold a train in Spider-Man movie, according to calculations published by Leicester university students in the Journal of Physics Special Topics?

Task 2. Sources mention that in the film "Spider-Man" he shot about 1 cm thick threads. What tensile force of 1 m^2 could this thread withstand?

Task 3. To what thickness was the 1 cm thick thread stretched into in the film if it had been doubled in length and the stopping distance found by the project participants is 900 m?

Task 4. It is known, that with 1 kg of spider‘s silk‘s thread you can wrap around the entire Earth. What would be the thickness of the mentioned thread?

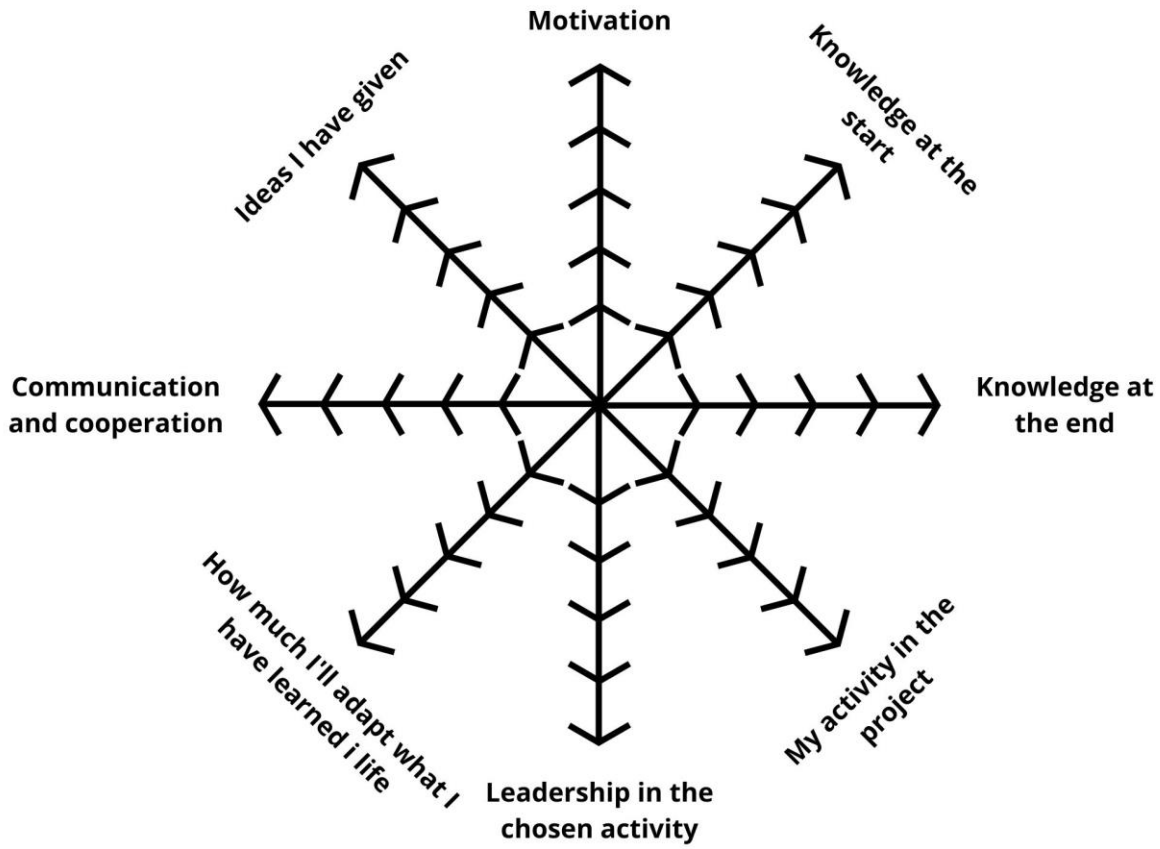
Task 5. It has been found that a 1 g of thread of a Darwinian spider can stretch to a length of 70 km. How thick would this thread be?

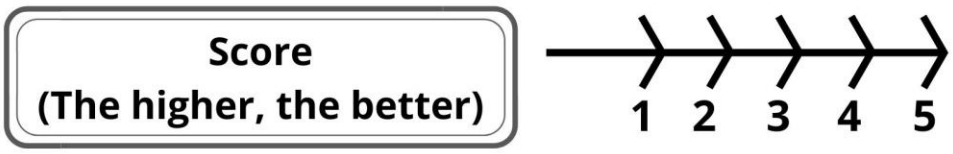
Task 6. Spiderman‘s silk thread is made out of 12 strings. What thickness are these strings?

Task 7. How much Nephilos spiders you would need to produce 1 g of silk if 1 pound of silk is produced by 27648 Nephilos spiders?

Task 8. How many spiders would be needed to produce threads that could stop the train if the thread thickness were 21.13 mm, the thread could stretch 35% from 21 m, and 61,000 Nephila spiders could produce 1 kg of spider silk at a spider silk density of 1.097 g/cm^3?

Annex 8 - Cobweb for self-evaluation





Can we live on Mars?

COUNTRY: Portugal

SCHOOL: Secondary School Daniel Sampaio

SUBJECTS/TEACHERS: Carla Vaz – Biology
Cristina Santos – Math
Paula Paiva – Physics

Movie	The Martian (2015)
Title	Why would it be difficult for man to survive on Mars?
Level (age of students)	16 and 17 years / 11th grade
Equipment needed	Computer /mobile Calculator A4 size checkered sheet of paper; pencil; rubber; protractor; ruler; drawing compass
Teaching aims	**Biology:** Research the main conditions of Mars that don't allow the development and maintenance of life, articulating with knowledge from other subjects (Physical and Chemical Sciences). **Math**: Definition of ellipse; drawing Mars orbit; determine the equation of Mars orbit and calculate the eccentricity. **Chemistry/Physics**: Relate the chemical and physical characteristics of Mars; calculate its escape velocity, deduce the equation and calculate its orbital velocity.
Learning outcomes	As a result of these activity students will be able to: • Research and systematize information, integrating previous knowledge to build new knowledge. • Formulate and communicate critical opinions scientifically based and related to Science. • Articulate knowledge from different subjects.
Methodologies/methods	Group work (3-4 students)
Activity phases and timing	Preview of the film by students. **1st Stage** - 45 minutes (Part A of the worksheet) to group search the different topics (physical and chemical characteristics of the planet Mars and habitability conditions).

	2nd Stage – 45 minutes (Part B of the worksheet) - Deduction of equations for calculation of orbital and escape velocity. **3rd Stage** – 90 minutes (Part C1, C2 and C3 of the worksheet) for practical activity (construction of orbits, deduction of ellipse equation, eccentricity calculation. **4th Stage** – 35 minutes of discussion activity: "Why would it be difficult for humans to survive on Mars?" **5th Stage** - 45 minutes to prepare and present the final product (Part D of the worksheet) - Padlet, for example. **6th Stage** - Self-evaluation - 10 minutes

Activity for Students

Name: _____ Date: ____ / _____ / ___

"Why would it be difficult for Man to survive on Mars?"

Mars is often called the 'red planet' because it appears as an orange-red star in the night sky. The color prompted the ancient Greeks and Romans to refer to it as their god of war. Today, thanks to exploratory and scientific satellites, we know that the appearance of the planet is due to the prevalence of rust in Martian rocks.

Mars is the fourth planet from the Sun. It orbits the Sun at an average distance of 228 million km, one and a half times the distance of the Earth, so any human visitors would find it very cold.

Even with the most powerful telescopes, it is very difficult to see the details of Mars. In the late 19th century, some scientists thought they saw straight lines crossing the planet's surface and joining greenish areas, which looked like cultivated areas. So scientists believed that straight lines were channels built by Martians to bring water to crops. The images taken by the spacecrafts have shown that these channels do not exist. There is no sign of life, plant or animal, on the planet.

In 1996, a group of scientists revealed to the world that they had found evidence of the presence of bacteria inside a meteorite from Mars. However, today this idea is not shared by most of their colleagues. If any form of life is found on Mars in the future, it would be the first proof that we are not alone in the universe.

"What are the physical and chemical characteristics of the planet Mars that can affect the habitability conditions on the planet? "

PART A – Research work on the physical and chemical characteristics of habitability on Mars

The first humans on Mars will face many problems. The air is about 100 times less dense than the Earth and does not have the same chemical composition. Human explorers will need to wear special suits every time they come out of their sealed homes.

Carry out research where you can identify the physical and chemical characteristics of the planet Mars that can affect the habitability conditions and build a table with the data you found.

"How to escape from Mars?"

PART B - Calculate orbital and escape velocity

Atmosphere retention is a relationship between the kinetic energy (or temperature) of gas molecules and the planet escape velocity (or its mass). The escape velocity is defined as the minimum velocity that a body must have to escape the gravitational pull of any celestial body, and can be calculated by the expression:

$$v(escape) = \sqrt{\frac{2GM}{r}}$$

Over here:

v - escape velocity (m/s)

G - universal gravitational constant

M -mass of the planet (kg)

R - radius of the planet (m)

1. Calculate the escape velocity from the surface of Mars and research how it influences the composition of its atmosphere and its uninhabitable for humans.
2. From Newton's Second Law and the Law of Universal Gravitation, deduce the expression for the orbital velocity of Mars and calculate its average value.

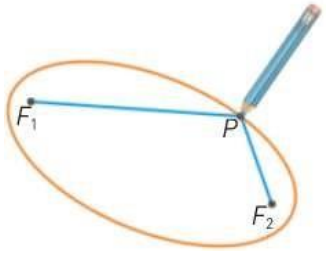
"What physical and chemical characteristics of mars are influenced by the eccentricity of its orbit?"

PART C - Discovering Mars Orbit; Calculate the eccentricity of Mars; Mars Orbit Equation

C1 - Introduction

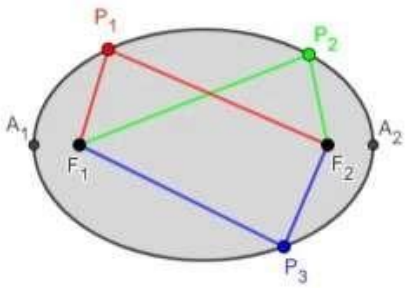
Ellipse

The ellipse is a very common figure in plane geometry. Present in everyday life, the ellipse describes, for example, the movement that the planets make around the Sun, known as orbit.



Analyzing it analytically, it has important elements, such as the foci, the major axis and the minor axis, in addition to the focal distance, which makes it possible to describe it through an equation. In mathematics, it is defined as the set of points whose sum of the distance between these points and the distance between each of their focuses is always constant.

What is an ellipse?

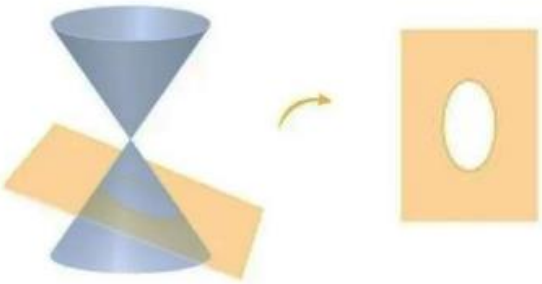


Given two points, F_1 and F_2, with a distance between them equal to 2c, we define as an ellipse the set of points P_n, whose sum of the distance between points P_n and F_1 with the distance between points P_n and F_2 is always constant and equal to 2a.

By definition, for this figure to be an ellipse, the distances will have to be equal to the constant 2a, which is nothing more than the distance from A_1 to A_2, so we have to:

$$\mathbf{dP_1F_1 + dP_1F_2 = dP_2F_1 + P_2F_2 = dP_3F_1 + dP_3F_2 = dAB = 2a}$$

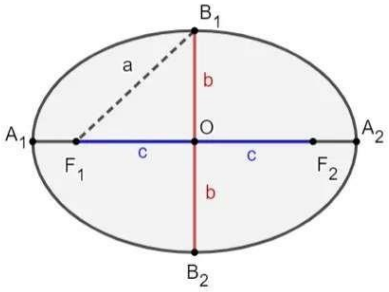
The ellipse is also known as a conic, because it is possible to obtain this geometric figure by making a section of a cone.



The ellipse can be found in the section of a cone.

Ellipse Elements

Given any ellipse, it always has two axes, the major axis, which contains the foci, and the minor axis. In addition, it has other important elements:



O → center of the ellipse

F1 and ***F2*** → ellipse foci

A1 and ***A2*** → vertices of the ellipse on the horizontal axis

B1 and ***B2*** → vertices of the ellipse on the vertical axis

2a → major axis (distance between A_1 and A_2)

a → semi major axis (half the distance between A_1 and A_2 equal to distance between F_1 and B_1)

2b → minor axis (distance between B_1 and B_2)

b → semi minor axis (half the distance between B_1 and B_2)

2c → focal distance (distance between F_1 and F_2)

Note also that it is possible to apply the Pythagorean theorem and, in this way, relate the parameters ***a***, ***b*** and ***c***:

$$a^2 = b^2 + c^2$$

Ellipse eccentricity

Another important relationship is eccentricity, the greater the eccentricity, the flatter the ellipse. The eccentricity is the ratio between length ***c*** and length ***a:*** $e = \frac{c}{a}$

As a > c, then, when we divide ***c*** by ***a***, we will always find a number greater than 0 and less than 1, that is, $0 < e < 1$. The closer to 1, the flatter the ellipse, and the closer to 0, the rounder it will be this ellipse, getting closer and closer to a circle.

Ellipse equation

In analytic geometry, it is quite common to describe geometric figures through algebra. Thus, with the studies of this conic, it was possible to develop the equation of the ellipse with center at the origin:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

In the equation:

- when $a > b$, then the foci of the ellipse will be on the x-axis and we have to: $a^2 = b^2 + c^2$
- when $b > a$, the foci of the ellipse are on the y axis, and we have that $b^2 = a^2 + c^2$.

C2 - Discovering Mars' Orbit using the Kepler's simplified method

Introduction:

In this activity we intend to discover the orbit of Mars from astronomical observation data in a similar way and more simplified than the discovery process experienced by Kepler (astronomer, astrologer and mathematician, Germany) did using the data he got from Tycho Brae (astronomer and mathematician, Denmark).

In this process to discover the orbit of Mars we did the following simplifications:

- the orbit of the earth is not a perfect circle with the sun exactly in the center it's pretty close but in fact the orbit is slightly elliptical and the sun is not quite in the center;
- also, the orbit of Mars is not exactly in the same plane as the orbit of Earth, it's actually a little bit tilted about 1,85 degrees.

A particularly interesting time in the orbit of Mars is the time called Opposition which happens every 26 months. When Mars is in opposition this means that:

- On Earth we look in one direction to see Mars and we look exactly in the opposite direction to see the Sun;
- Mars and the Sun appears in opposite directions in the sky;
- the SEM angle (angle between the Sun, Earth and Mars) is 180 degrees;
- when Mars is in opposition you can draw a straight line from the Sun through the Earth into space and you will find Mars.

Kepler was sure Copernic (mathematician and astronomer, Poland) was right when he said it took the Earth a year to make a complete circle around the sun. Kepler knew that Mars revolves around the Sun somewhere outside Earth's orbit, but he didn't know how far away and he also didn't know the shape of Mars' orbit.
Kepler also knew that Mars takes 687 days to make a complete revolution around the Sun, so 1 year on Mars has 687 days. Watch the Video to learn more about it.

Material:

- A4 size checkered sheet of paper
- pencil;
- rubber;
- protractor;
- ruler;
- drawing compass.

Procedure:

To find the orbit of Mars we need the data in the following table:

ORBITAL POSITIONS DATE	Heliocentric Longitude Earth (degrees)	Geocentric Longitude Mars (degrees)	Opposition number
27.08.2003	334	334	1
14.07.2005	292	22	
07.11.2005	45	45	2
25.09.2007	2	88	
24.12.2007	92	92	3
10.11.2009	48	131	
29.01.2010	129	129	4
17.12.2011	85	166	
03.03.2012	163	163	5
19.01.2014	119	199	
08.04.2014	198	198	6
24.02.2016	155	236	
22.05.2016	242	242	7
09.04.2018	199	283	
27.07.2018	304	304	8

13.06.2020	**263**	**351**	
13.10.2020	**20**	**20**	**9**
31.08.2022	**338**	**66**	

Table 1 – Heliocentric Earth and Mars Geocentric Longitude Positions

Heliocentric longitude is the celestial longitude of a celestial body as seen from the center of the Sun - opposed to geocentric longitude.

Geocentric longitude is celestial longitude based on the earth's center - opposed to heliocentric longitude.

The data in Table 1 are pairs of observations of heliocentric longitude of Earth and geocentric longitude of Mars when the Sun-Earth-Mars system is in the Opposition configuration (Sun on one side, Earth in the middle and Mars on the side opposite the Sun) and exactly 687 days after this configuration.

It is observed that after this period of time, Mars will not be in the same position in relation to the Earth, because our period of translation (a complete revolution around the Sun) is 365 days.

Adopting a circular orbit for the Earth with the Sun at the center we can determine by triangulation, from each pair of data, the position of Mars relative to the Sun along the opposing directions, as illustrated in the Figure 1, and by determining the successive positions of Mars we can draw its orbit.

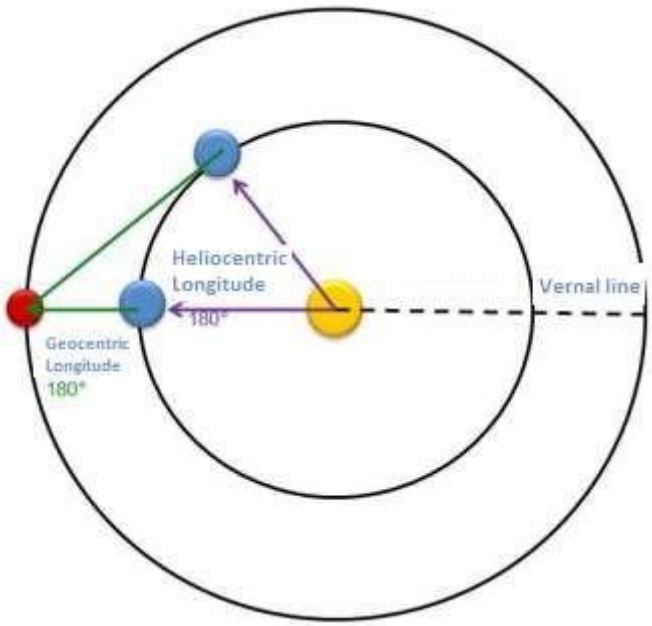


Figure 1 - Triangulation for determining the positions of Mars in its orbit. Representation is not to scale

Let's start:

1) With the help of a drawing compass, draw in the center of an A4 size sheet of paper a circle with a radius equal to 4 cm, this will represent the Earth's orbit.

2) From the origin of the circle, draw the two axes (horizontal and vertical, in the reference frame) and mark the angles corresponding to the arcs in the circumference (0°, 90°, 180°, 270° and 360°).

3) Consider the 0° or 360° position as the origin of the coordinate system,

4) Considering the data in Table 1, identify the angle with the protractor corresponding to the heliocentric longitude of the Earth (334°) of the first pair of points (Opposition) and mark this position on the circle of the Earth's orbit. Then indicate this direction by drawing a straight line from the circle's origin, passing through the newly marked point and going to the end of the sheet; Use the protractor to identify the angle corresponding to the heliocentric longitude of the Earth (292°) of the second pair of points (Opposition) and mark this position on the circle of Earth's orbit.

5) From the position marked for Earth in step (4), draw a horizontal straight line (represented by a dashed line in Figure 2). Mark point A with the protractor at the angle of the geocentric longitude of Mars (22°) to the horizontal line. Align the ruler with E_1 and point A, and mark the intersection with the line drawn in step 3 (see Figure 2);

6) At the intersection of the lines traced in steps (3) and (5) we mark the point M_1, corresponding to the first position determined for Mars;

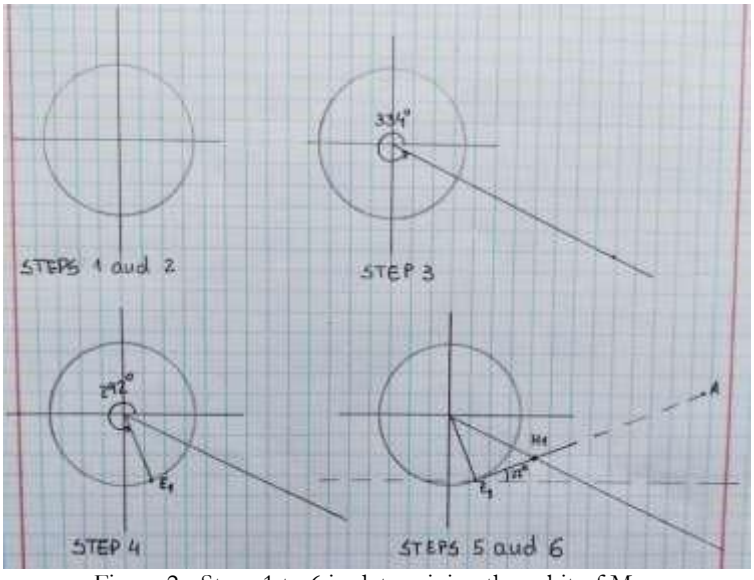


Figure 2 - Steps 1 to 6 in determining the orbit of Mars

7) Repeat the procedure successively for the other eight pairs of positions in Table 1, until determining the nine positions of Mars;

8) Gently draw curves between Mars positions to trace its orbit.

Discussion:

1) Does Mars' orbit have the same geometric center as the circle representing Earth's orbit?
2) Is the shape of Mars' orbit circular like Earth's orbit? If not, what shape is it?

You've just achieved the same observations as Kepler.

Next, Kepler looked for a geometric shape that would consider the shape of the orbits of Mars and Earth, and at the same time, place the Sun in the same position for both.

C3 - Equation of the orbit of Mars and calculation of its eccentricity

After a lifetime of study, Kepler deduced three laws that explain planetary motion and make us understand how the universe is structured. Kepler's laws can be used to study the motion of planets around the Sun and the motion of natural and artificial satellites around planets.
To determine the equation of the orbit of Mars and calculate its eccentricity, let's just think about Kepler's first law.

Kepler's First Law

The planets describe elliptical orbits in their movement around the Sun, one of the focuses being occupied by the Sun. The distance between the planets and the Sun varies.
The point on the trajectory closest to the Sun is called Perihelion; and the farthest point, Aphelio

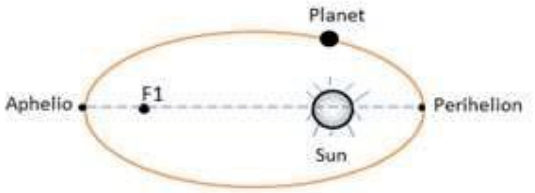


Figure 3 – Kepler's first Law

Discussion:

Considering the data in Table 2 and a possible representation of the elliptical orbit of Mars in Figure 4:

Orbit Characteristics	Values (km)
Semi-major axis	227939100
Perihelion	206669000
Aphelion	249209300

Table 2 – Mars' Orbit Characteristics

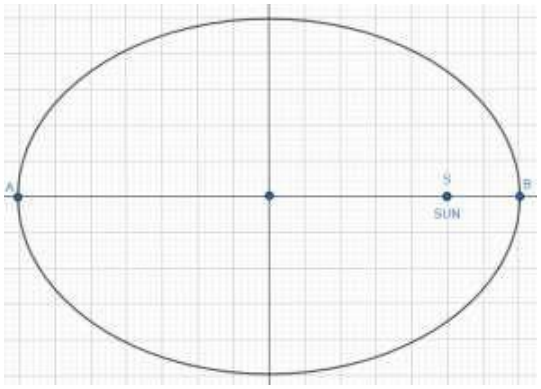


Figure 4 – Mars' orbit

1) Write the equation for the orbit of Mars in the form:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

Indicate the values in UA (astronomical units) to six decimal places.

Note: 1 UA = 149 597 870.7 km

2) Calculate, to six decimal places, the value of the eccentricity of the orbit of Mars.

3) Although the orbits of Earth and Mars are both elliptical, those of Earth can be approximated to a circle but that of Mars cannot. How do you justify this fact?

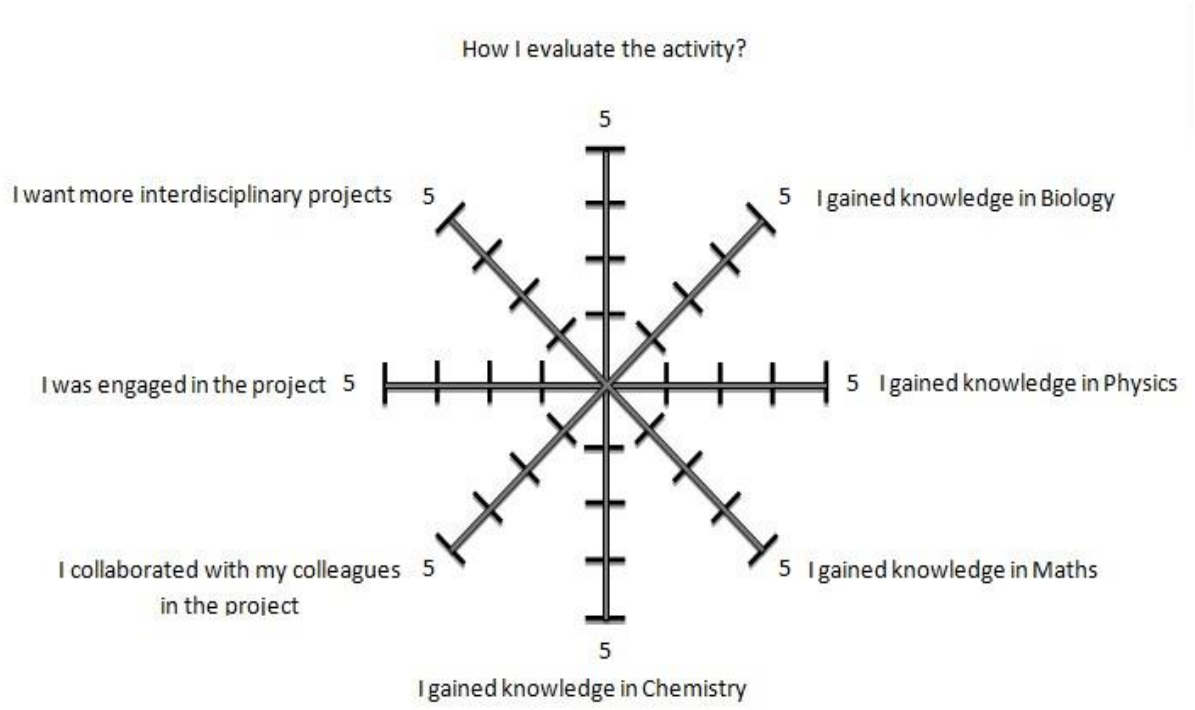
4) Explain how the high eccentricity of Mars' orbit can influence conditions of habitability on Mars.

PART D - CONCLUSION

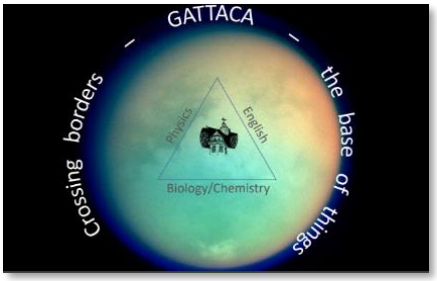
After carrying out the various activities proposed throughout this form, now prepare a Padlet to present to the class, where you answer the initial question: *Why would it be difficult for man to survive on Mars?*

SELF-EVALUATION

Fill the diagram bellow **(5 – best; 1 – worst)**



Gattaca



COUNTRY: Germany

SCHOOL: Johann-Heinrich Voss-schule

SUBJECTS/TEACHERS:

Sabine Steenken (Biology, Chemistry)

Dr. Danielo Behnke (Physics, Mathematics)

Christopher Raschpichler (Physics, Chemistry, Computer Science)

Sylvia Blunck (English, Biology)

Birgit Setje-Eilers (German, Biology)

Alheid Szellinski (English, German)

Movie	Gattaca (1997)
Title	Crossing borders: future society, outer space, genetics
Level (age of students)	15-18 years
Equipment needed	Projector, computers Lab materials Thin wire, beads and hooks for earrings
Teaching aims	**Physics:** escape velocities (equivalence of forces and energy-conservation, simple calculus) **Biology:** basics of DNA **English**: practising listening and viewing comprehension; analysing component parts, discussing genetic engineering
Methodologies/methods	Group work Individual work Round Robin Experiments
Activity phases and timing	4*45 min – English activity 6*45 min – Biology activity 4*45 min – Physics activity

Annex 1 – English Worksheet – Creating a better world

General goals:

+ practising listening and viewing competences
+ working out component parts, practising methods of analysis of texts
+ realising, discussing and evaluating that this fictional world consists of a bipartite society on the basis of genetic engineering

Lesson 1: Let´s watch the opening scene of the movie again (ca. 4 minutes).

Tasks (1+2 in written work, presentation of results, discussion; 3: orally)

1. Examine the two quotations at the beginning of the movie by also analysing the language. Which attitude towards nature is shown by them? Comment on both of them, please.
   Blackboard (or the like)
   A: Consider God´s handiwork: who can straighten what He hath made crooked? (*Ecclesiastes 7:13*)
   B: I not only think that we will tamper with Mother Nature. I think Mother wants us to. (*William Gaylin, American psychiatrist and bioethicist*)
2. After these intertitles two immensely enlarged items are shown falling on the ground in slow motion. Next, you can see a man cleaning and shaving himself with dedication. What do you think these items are and what might be their significance?
3. Point out the function of this opening scene of the movie and evaluate it.

Lesson 2: Genetic engineering – The Genetic counselling Office (bonus material: Special Features/Deleted Scenes: Eighth Day Center)

cf vocabulary "Genetic Counselling Office"(to be worked on before watching)

Task 1: After the first viewing, state your spontaneous reaction to the conversation in one sentence. (Everybody reads this out, Round Robin).

After the second viewing:

Task 2: Outline the genetic process that is discussed here in a few sentences. (IVF)

Task 3: Explain what the geneticist means when he says: "For a little extra I could also attempt to insert sequences associated with enhanced mathematical or musical ability. "

Task 4: Describe the view of man/mankind that is revealed here. In what way will this baby be different from the babies born nowadays?

Lessons 3+4: Genetic engineering – Characteristic Features of Gattaca`s Future Society and forming an own point of view

Task 1: Read the following quotations. (cf. copy "Quotations ")

Task 2: In your own words, describe the sad and difficult situation both of the in-Valids and the Valids (in the latter case, use Jerome Eugene Morrow as an example).

Task 3: Analyse the terms reserved for both groups. What is revealed by each expression and what change in the view of man/woman can you detect?

Task 4: Copy the grid and fill it out, please:

Bipartite Society

Basis:

Types of humans:

Characteristics:

Problems faced:

Task 5: Group work (4-5 pupils)

+ How do you view the prospects of bio-engineering gene manipulation?
+ In your opinion: will it be a blessing or a curse?

Take turns stating your first reactions to the questions below. Then agree on a common position in your group, find pros and cons and present it to the class (form: speech).

Vocabulary "Genetic Counselling Office"

Please find the right definitions for each word by using your electronic dictionary and write them down.

(to) extract **enhanced** **(to) eradicate**

crick **(to) implant** **obesity** **(to) conceive**

sequence **(to) fertilise** **(to) screen** **susceptibility**

pre-disposition **prejudicial** **myopia** **womb**

The exercises are adapted from the following source: "Future Worlds", Klett Verlag, ISBN 978-3-12-577475

Annex 2 – Biology Worksheet – Cracking the code

Worksheet I

1. **Warming-up:** Match the terms on the left with the definitions on the right.

1 gene	a. part of a living cell that contains genes
2 genome	b. organic chemical in which genetic information is encoded
3 chromosome	c. technique for making genetically identical copies of an organism
4 uterus	d. done outside the body, i.e. in a laboratory
5 in vitro	e. the smallest unit of hereditary information
6 cloning	f. the complete set of genes belonging to an organism
7 DNA	g. cell that is capable of developing ito one of several types
8 nucleus	h. organ in a women's body in which an embryo develops
9 genetic engineering	i. thread-like structure that carries genes
10 stem cell	j. technique of artificially manipulating the genetic structure of an organism

Solution: _____ _____ _____ _____ _____ _____ _____ _____ _____ _____

Source: Topics in Context Science, Technology and the Environment Cornelsen Verlag, 2011

Worksheet II

The key to the manipulation of an organism's genetic make- up (genetic engeneering) lies in the structure of the **DNA** (desoxyribonucleic acid).

The **DNA** carries the genetic information for constructing all the components of our body. It contains the 'genetic code '. Genes are part of the **DNA** and are the basic units which influence a person's appearance, abilities, health and behaviour.

It is highly similar among all living beings.

As **DNA** is very important for life it's worth to find out *what it looks like* and *make it visible.*

DNA-extraction from onions (or tomatoes)

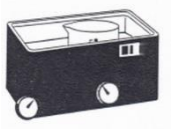
Material:

- 5 ml washing-up liquid, ½ teaspoon common salt, 50 ml water, 1 medium-sized onion, beaker
- water bath
- mortar
- funnel, coffee filter or paper tissue
- mild detergent, ethanol (98%, chilled), glas rod (or wooden stick)

Experimental procedure:

1. Mix water, washing-up liquid and salt in a beaker. Cut the onions into very small pieces and give them into the solution.

2. Put the beaker for 15 minutes into a 60°C water bath.



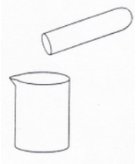
3. Afterwards cool it for some minutes in cold water. (ice water)

4. Now use a mortar to crush the pieces of onion until a grainy mush arises.

5. Give the mixture into a funnel with a coffee filter.

6. Measure 2-3 cm^3 of the filtrate and add some grains of the detergent.

7. Mix the approach well and overlay it carefully with cold alcohol.



8. Now observe how **DNA** streak-like precipitates from the alcohol solution. You can remove the white DNA-threads with a glas rod.

Worksheet III

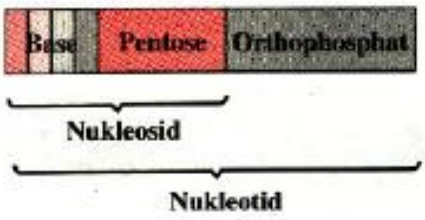
Have a closer look at the components and the structure of the DNA.

The Structure of DNA

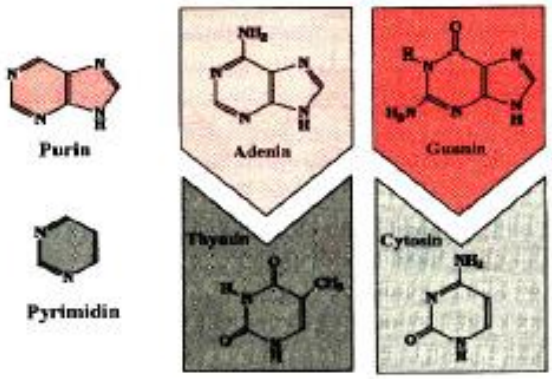
All the necessary pieces of information concerning the structure of a living thing are directly or indirectly carried/stored in one's DNA.

The structure of DNA was decoded in 1953 by Francis Crick (left) and James Watson (right), who were awarded with the Noble Prize for this discovery in 1962.

Nucleic acids consist of small component parts which are called nucleotides. One mono-nucleotide is built up of an organic base which also contains nitrogen, deoxyribose (sugar) and a rest of phosphate acid resp. a phosphate group. The bonding between a base and deoxyribose is called nucleoside.



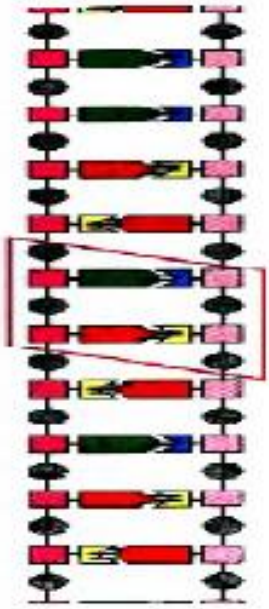
The names of the bases are adenine, guanine, cytosine and thymine. Adenine and guanine are purine bases, cytosine and thymine are pyrimidine ones.



Many nucleotides form polynucleotides, i.e. the nucleic acids. Under formation of water mononucleotides esterify.With the help of phosphorus acid carbon atom no 5 of the antecedent nucleotide is joined with carbon atom no 3 of the following nucleotide, i.e. from 5'- 3'- end. A polynucleotide strand (or chain) is the result. The sequence of these nucleotides depends on the species.

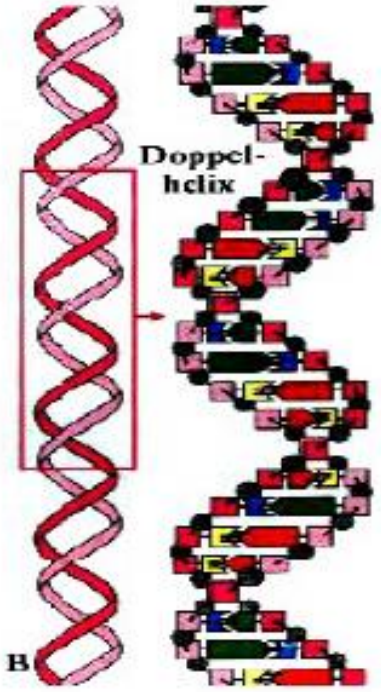
Two polynucleotides merge to DNA. Here the bases bond in a system of complementary pairing, between adenine and thymine are 2, between guanine and cytosine are 3 hydrogen bonds formed (= complementary base pairs).

Schematic diagram:



This "rope ladder" turns right into itself. This is called double helix.

Structure DNA (schematic diagram):



Task 1: Explain the diagram to each other.
Task 2: What does "Gattaca" actually mean?

Worksheet IV - *How to make a DNA double helix with beads*

To get a deeper insight into the structure of the macromolecule you could make decorative jewellery. 😊

Material

- thin wire (copper wire of an electric coil)
- round beads in two different colours (sugar, phosphate)
- buggle beads in four colours for the bases adenine (A), cytosine (C), guanine (G) and thymine (T)
- nickel-free hooks for earrings

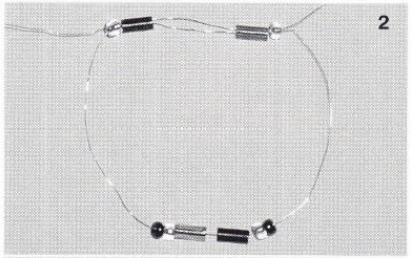
That's how it's done:

Determine the colours for the bases (A,T,C,G), sugar (S) and phosphate (P).

Measure about 85 cm of wire and string the following beads in the given order (**1**):

–T – P – Z – P – A – T – P – Z – P – A

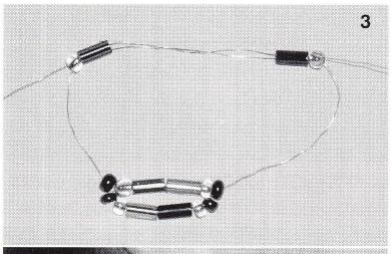
Now pull the right end of the wire through the outer beads T – P on the left hand side and the left end of the wire on the outer right hand side through the beads P – A (**2**)



In the middle two base pairs arise: A –T and T – A.

String round beads for S – P to the left and the right end of the wire and one buggle bead for the base of one base pair, for example G on the left hand side and C on the right hand side.

Once more pull the right end of the wire through G – P, the left end of the wire through P – C. (**3**)



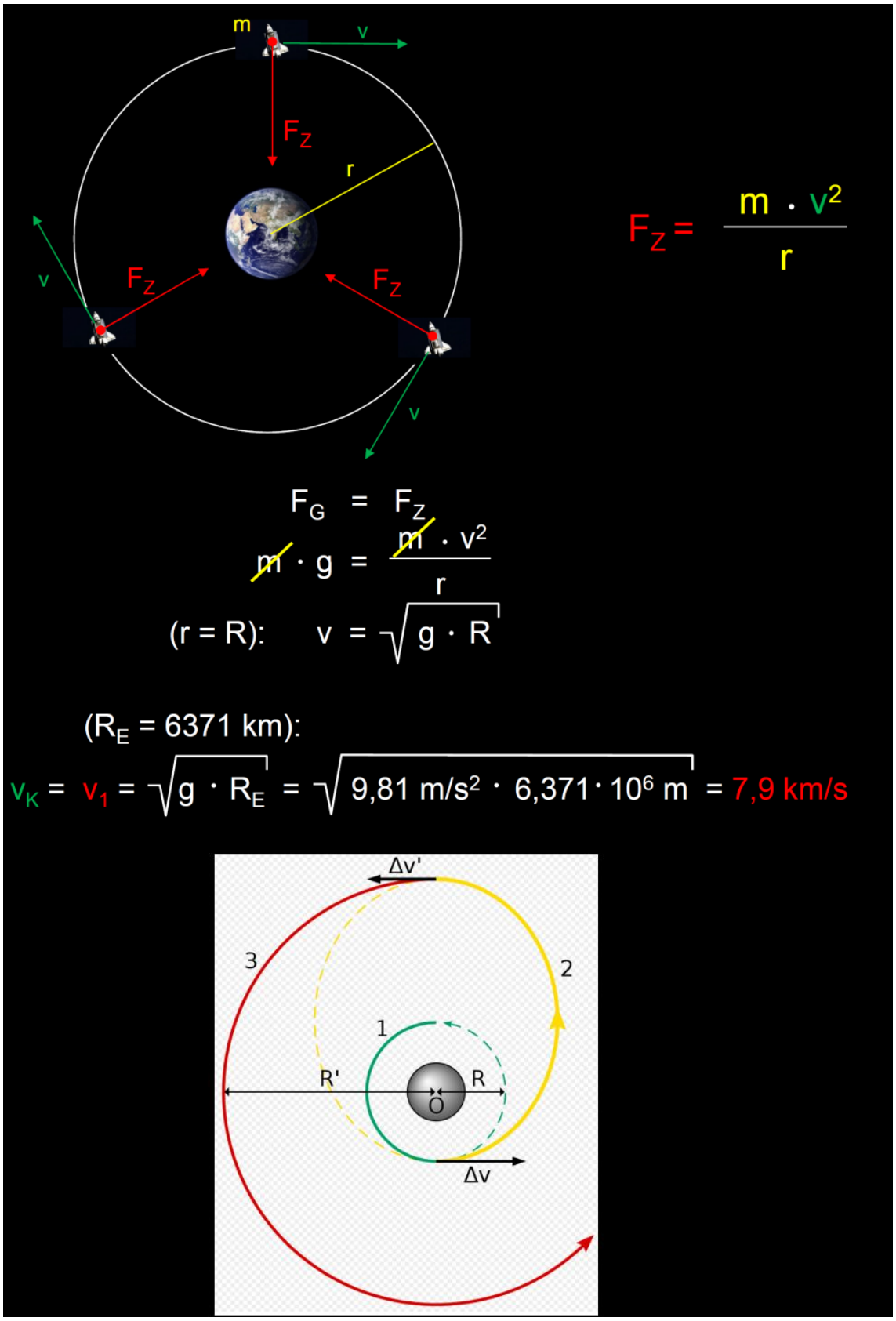
Repeat steps 3 and 4 until at least 12 base pairs or another multiple of three are stringed together.

Fix the hook with a wire eyeled between the two buggle beads for the last base pair.

And now bring a slight rotation into the rope ladder – and that's it . The double helix is finished (**4**)

Source: Inge Kronberg, DNA-Doppelhelix aus Perlen, UB 326,2007

Annex 3 – Physics Worksheet – 1st cosmic velocity



Gambozino's Hunt

COUNTRY: Portugal and Hungary

SCHOOL: International groups

SUBJECTS/TEACHERS: Carla Vaz – biology

Hortobágyiné Kard Eszter – IT

Movie	Creation (2009)
Title	Gambozino's Hunt - a Natural Selection Simulation
Level (age of students)	16 and 17 years / 10-11th grade
Equipment needed	Plastic Cups Table towel/sheet Tools: plastic knives, plastic forks and plastic spoons and tape Biological material: beans, corn; lentils; pasta Computers with internet connection
Teaching aims	**Biology:** Natural selection acts on heterogeneous populations, which makes better adapted individuals live longer and originate more offspring. The following generations have a higher number of more able individuals. **IT**: Mathematical operators (and, or) Basic Excel calculations and functions (AVERAGE, AND, OR, COUNTIF)
Methodologies/methods	Group work
Activity phases and timing	Part A – 45 min – Biology activity Part B – 45 min – IT activity

Activity for students

"How can one or more characteristics of a population change over time as a result of natural selection?"

"How can we use random numbers for simulating a real process?"

Part A - Let the hunt begin!

1. Form 4 groups of students. Each group will represent 1 predatory species. Four ferocious species will be *formed:* ***Alunus afiadus***, ***Alunus tridentatus***, ***Alunus spatuladus*** *and* ***Alunus adesivus***, depending on the knife, fork, spoon or duct tape, respectively.

2. Each group formed will be assigned, by lot, the species it represents and its capture body. The organ represents a part of your predator body, specializing in the capture of food (such as the beak of a bird). This organ is the result of the expression of the species' genes.

3. Table towel represents the prey habitat.

4. Spread homogeneously 100 specimens of each type of biological material provided by your teacher (e.g. beans, corn, lentils and pasta) through the table. These will be the fangs. The prey belongs **to a single species**, known as Gambozino *(Gambozinus odonthosabrinus)*. In this species there is enormous intraspecific variability, with different shapes, sizes and colors. These features are hereditary.

5. At the teacher's signal each clan begins the hunt for the Gambozinos, which will last 1 minute. Attention to the rules:
   - **a)** You must capture as many Gambozinos as possible to prevent the extinction of your population (interspecific competition simulation);
   - **b)** You can only capture **one Gambozino at a time**;
   - **c)** You **should only use** your capture organ (knife, fork, spoon or duct tape);
   - **d)** After capturing a Gambozino you must deposit it in your clan's cup for later counting,
   - **e)** You can **capture any variety** of Gambozinos.

6. When the teacher marks the end of the hunting season, record the results on the Excel sheet. (Annex 1)

7. The poulation that captures less Gambozinos **is extinguished**. The extinct clans should be quietly watching the story unfold.

8. For each variety of Gambozinos count the survivors and **double that number** by spreading new ones of the same type on the table (habitat). For example, 50 bean gambozinos of the initial 100 were hunted. 50 survived. Then add 50 more equals. Do the same for the remaining varieties.

9. Repeat the simulation 2 more times (2 generations of gambozinos), from step 5. Don't forget to fill in the Excel sheet.

Discussion

1. Which predators went extinct first, and why? (What tool did they use? What other factors may have contributed to its extinction?)

2. What are the most advantageous traits for predators? Justify.

3. Why has the number of surviving Gambozinos been doubled?

Part B – Simulating the evolution of a population.

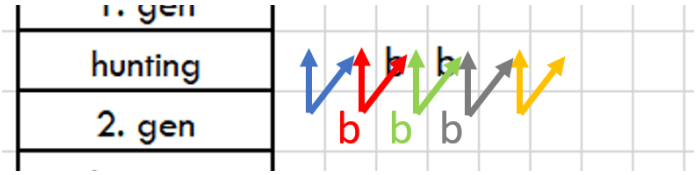
1. Make a copy of the Excel file!
2. Now we will investigate the Gambozino's population evolution! For making a simulation for many generations we will need an average data about how many Gambozinos will survive a hunting season. In column `I`, fill the cells with a proper formula which tells: What proportion of the Gambozinos survived this hunting season?
3. In B35:B38 cells calculate the average survival rate of each Gambozinos!
4. Now we can start preparing the simulation! (Annex 2)
    a. On the `Simulation_template` worksheet fill the first column!
    b. From D2 in each cell represents one potential Gambozino individual. If there is a character in the cell (for example *"b"* when we are talking about beans) this individual is alive, if there is nothing in the cell, or just a " ", there is no Gambozino alive.

The first row represents the first generation, the full Gambozino population. Fill each cell with a *"b"*!

c. The second row symbolizes the hunting season, where many individuals will die. Generate a random number with Excel-function RAND(). Combine this with another function, IF(). IF function needs 3 parameters. The first parameter is the logical comparison: Use RAND function here! Examine that the value of RAND function is smaller than the average surviving rate in cell A6 or not! If it is, write a "*b*" here because this individual survived otherwise write a simple " "!
Copy this function for this row but be careful with the cell references!

d. Use conditional formatting for the whole worksheet! If there is a "b" in the cell, fill this cell with some background color! *Clue: Use the same color as letter color, this was you won't see the letters in the cell!*

e. The third row symbolizes the method when we doupled the amount of the Gambozinos.
Fill this cell with a function: If there is a "b" in the cell above this cell or right above this, "b" should be here also. Otherwise there shouldn't be anything!



f. The new hunting season is very similar to the first one but you have to complete it! In the logical comparison you have to think about what if there is no individual above this cell! In this situation there is nothing what could survive!

g. Now copy down the last two rows! Make at least 10 generation!

h. After the last column make a headline: `Number of individuals`!

i. Calculate how many individuals are there in this season! Use COUNTIF function!

j. Make a chart from these datas! You can draw a trendline in this chart!

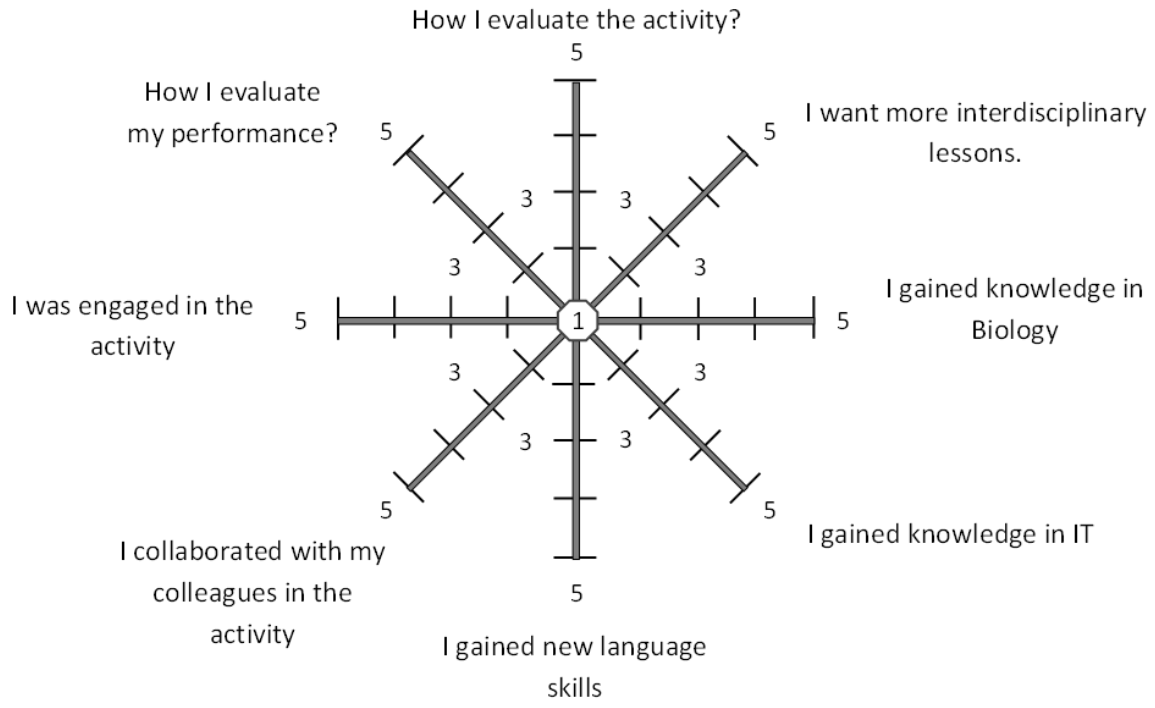
Discussion

1. What do you observe if you change the surviving rate in the simulation?

2. When will a population go extinct? How long does it take? How changed the velocity of the process over generations?

Self-Evaluation

Fill the diagram bellow **(5 – best; 1 – worst)**



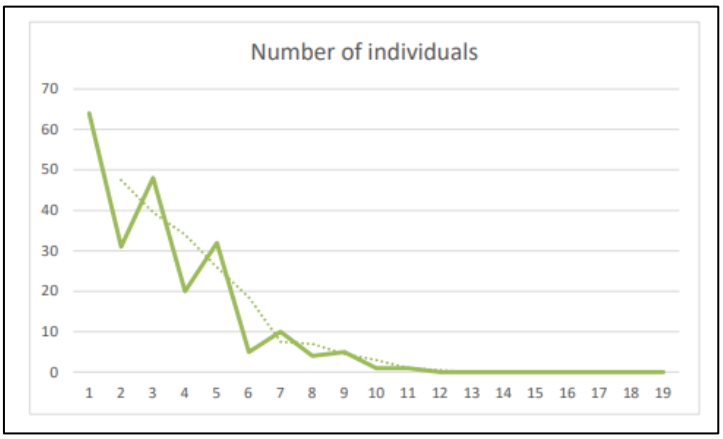
Annex 1 – An example for the recording the results

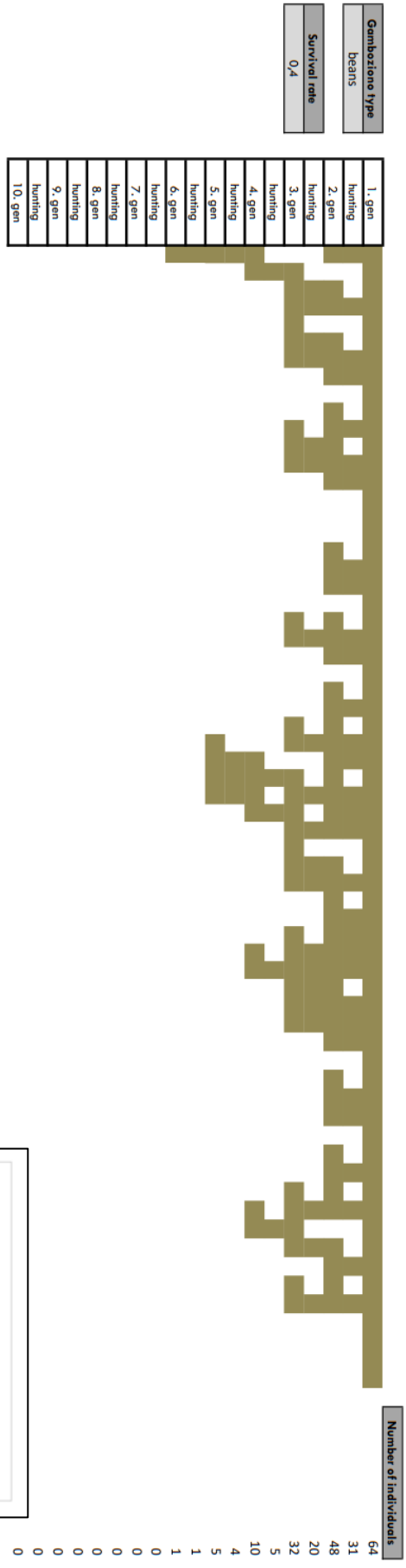
1st generation of Gambozinos		predators 1 spoon	predators 2 fork	predators 3 knife	predators 4 tape	Total	Survivors	
Lentils	100					0	100	
Corn	100					0	100	
Pasta	100					0	100	
Beans	100					0	100	
Total	400	0	0	0	0	0		

2nd generation of Gambozinos		predators 1 spoon	predators 2 fork	predators 3 knife	predators 4 tape	Total	Survivors	
Lentils	200					0	200	
Corn	200					0	200	
Pasta	200					0	200	
Beans	200					0	200	
Total	800	0	0	0	0	0		

3rd generation of Gambozinos		predators 1 spoon	predators 2 fork	predators 3 knife	predators 4 tape	Total	Survivors	
Lentils	400					0	400	
Corn	400					0	400	
Pasta	400					0	400	
Beans	400					0	400	
Total	1600	0	0	0	0	0		

Annex 2 – An example for the simulation





Discover and Uncover with Science: Everyday and Nature Phenomena

Project Plan

Title	Discover and Uncover with Science: Everyday and Nature Phenomena
Level (age of students)	16 and 17 years / 10-11th grade
Equipment needed	Computers Boxes (Annex 2)
General aims	Interdisciplinary work (Biology/ Chemistry/ Physics/ Mathematics) Collaborate working Improving communication skills Arousing interest/curiosity Problemsolving Research skills Explaining everyday phenomena
Methodologies/methods	Group work Research
Activity phases and timing	Part 1 – 90 min – Warming up to the task Part 2 – 4*90 min – Groupwork with the boxes Part 3 – 2*90 min - Presentation results

Annex 1 - Activity for the students

Instructions for groups

Look through the things in the box and think of one everyday phenomenon you could describe, explain and illustrate with the help of these things. It is not obligatory to use everything that is in the box!

Make sure that your explanation and experiment covers at least two subjects from the followings: **biology, chemistry, physics**, (+maths, IT)!

1. Find a scientific explanation for the chosen everyday phenomenon!
    a. Prepare a presentation or a digital infographic! (You can choose the platform: for example PowerPoint, Prezi, Canva, Genially etc.)
2. Carry out an experiment or build a model!
    a. You can use anything that is in the tool box!
    b. Prepare the description of the experiment (materials, hypotesis, main steps, results and conclusions) or the sketch of the model!
3. Be prepared to share and show your results to the other groups!

Annex 2 - Contents of the boxes

Content tool box

- pair of dividers
- hammer
- cutter
- set square
- food colouring
- glue pistol
- magnets
- baking powder
- vinegar
- kettle
- (air) pump
- thermal camera
- microcontroller/ Arduino
- polystyrene

Odds and ends in every box

- magnets
- scissors
- ruler
- paper clips
- wire
- rubber bands
- drawing pins
- chewing gum
- Smarties
- bananas

Box 1 ("Climate change")[3]

- plastic waste
- leaves, pebbles, sand
- boiled egg
- soapy lather/bubbles
- metal clip
- ice cube form
- candle
- (food colouring, cf. tool box)
- (salt
- plastic bottle
- plastic bags
- tin foil
- cling film
- tooth brush
- socks
- baking soda

Box 2 ("Energy")

- sugar
- pieces of wood
- ball(s)
- matches
- potatoes
- nails
- lemon
- coins
- coil springs
- wool
- toothpicks
- water bottle
- puzzle pieces
- baking soda
- piece of gutter
- hair brush

[3] Working titles are not to be given to pupils!

Box 3 ("Space/Atmosphere")

- plastic bottle
- mirror
- balloon
- candle
- glitter
- feathers
- hose
- mustard
- baking tins (stars)
- baking soda
- LED bulb
- piece of cloth
- magnifying glass
- cell phone
- Oreo biscuits
- photovoltaic cells

Box 4 ("Sports")

- ball(s)
- specific weights
- water bottle
- rope
- socks
- chocolate
- minerals
- baking soda
- coil springs
- grapes
- medals
- chess figures
- piece of wood
- deodorant
- domino
- ice cubes

Learning Circles

Project plan

COUNTRY: Lithuania

SCHOOL: Pakruojis „Atzalynas" Gymnasium

SUBJECTS/TEACHERS:

Biology (Daiva Makauskienė)

Chemistry (Vita Gudonienė, Rasa Augustinaitienė)

English (Rasa Stravinskienė, Rima Leimontienė)

Physics (Rasa Bertulienė)

Mathematics (Rita Vinskūnaitė)

Self- assessment and evaluation (Rita Vinskūnaitė and Rasa Bertulienė)

Title	Science Learning Circle
Level	10-12 grade
Equipment needed	PC's, paper sheets, markers
Teaching aims	To help students to learn more about Theodor von Grothuss works by analysing scientific articles and searching for relevant information in study groups
Learning outcomes	• Increased knowledge of Theodor von Grothuss works and the scientist's input in chemistry, physics, and biology. • Increased creativity, artistic, cooperation, analytical skills • Ability to revealing the main idea of the text and use additional material purposefully, presented the valid ideas and thoughts in a concrete and relevat way. • Ability to make conclusions and generalisations.
Methodologies/methods	Methods „Study Circle" and „Placemat"[4] Individual and group work[5]
Activity phases and timing	**Step 1** 1.1. Students are presented with the evaluation process and criteria and the articles (given a copy in paper and e-format) 1.2. The students read the article.

[4] You can read more about the „Placemat" here.

[5] Students work in four groups consisting of 6 people in each group. They will analyse and work on different articles in each group.

	1.3. Each group member is assigned one part of the article, which he must go through in more detail and prepare a summary that he will have to present to his group members.[6] **Step 2** 2.1. The teacher organises the first meeting. 2.2. Each group member writes down his main thoughts regarding the part of the article he analysed on the sheet – placemat and then presents his prepared summary. 2.3. After presenting parts of the article, the group members agree and write down the main points they learned in the middle of the sheet – placemat. 2.4. The teacher assigns homework- to find additional material/information related to the topic of the article material and prepare to talk about it to the group members. **Step 3** 3.1. The teacher organises the second meeting. 3.2. Each member of the group writes down short notes, additional information on the same sheet – placemat filled out during the first meeting, and then briefly tells the others from which source/article he/she found additional material 3.3 After the brief presentations, students write the main points down in the middle of the same sheet – placemat (the group agrees what was most important, most valuable). 3.4. Self-evaluation of students. 3.4. The teacher assigns homework for a group - to prepare a presentation (up to 10 minutes, PowerPoint or other selected visual format with verbal comments) about the results of the studies on their article for other groups. **Step 4** 4.1. The teacher organises the third meeting. 4.2. Students present the results of their work in study circles. 4.3. Evaluation/assessment of the student's presentations and work in a study circle
Evaluation tool	Tool „Target" Material for organising the evaluation: • *Annex_1_Recommendations and steps for the evaluation* • *Annex_2_Self-evaluation form*

[6] Students work individuallly to complete the step 1.2 and 1.3.

	• *Annex_3_ Criteria for evaluation of group work on Placemat* • *Annex_4_Criteria for presentation evaluation* • *Annex_5_Evaluation sheet of study circle activities with criteria* • *Annex_6_The Target evaluation form*

Resources and articles used:

- *Concerning the origins of charge transfer in the micro-structure of matter: The contribution of Theodor von Grotthuss* by Juozas Al. Krištopaitis (2006)
URL: https://www.sciencedirect.com/science/article/abs/pii/S001346860600315X
- *Theodor von Grotthuss' Contribution to Electrochemistry*
by Rasa Pauliukatė, Jurga Juodkazytė, Rimantas Ramanauskas (2017)
- *An update of the chemiosmotic theory as suggested by possible proton currents inside the coupling membrane*
by Allesando Maria Morelli, Silvia Ravera, Daniela Calzia and Isabella Panfoli (2018-2019)
- *The Grotthuss mechanism* by Noam Agmon (1995)
- Placemat sheet - https://www.learnalberta.ca/content/sssm/html/placematactivity_sm.html

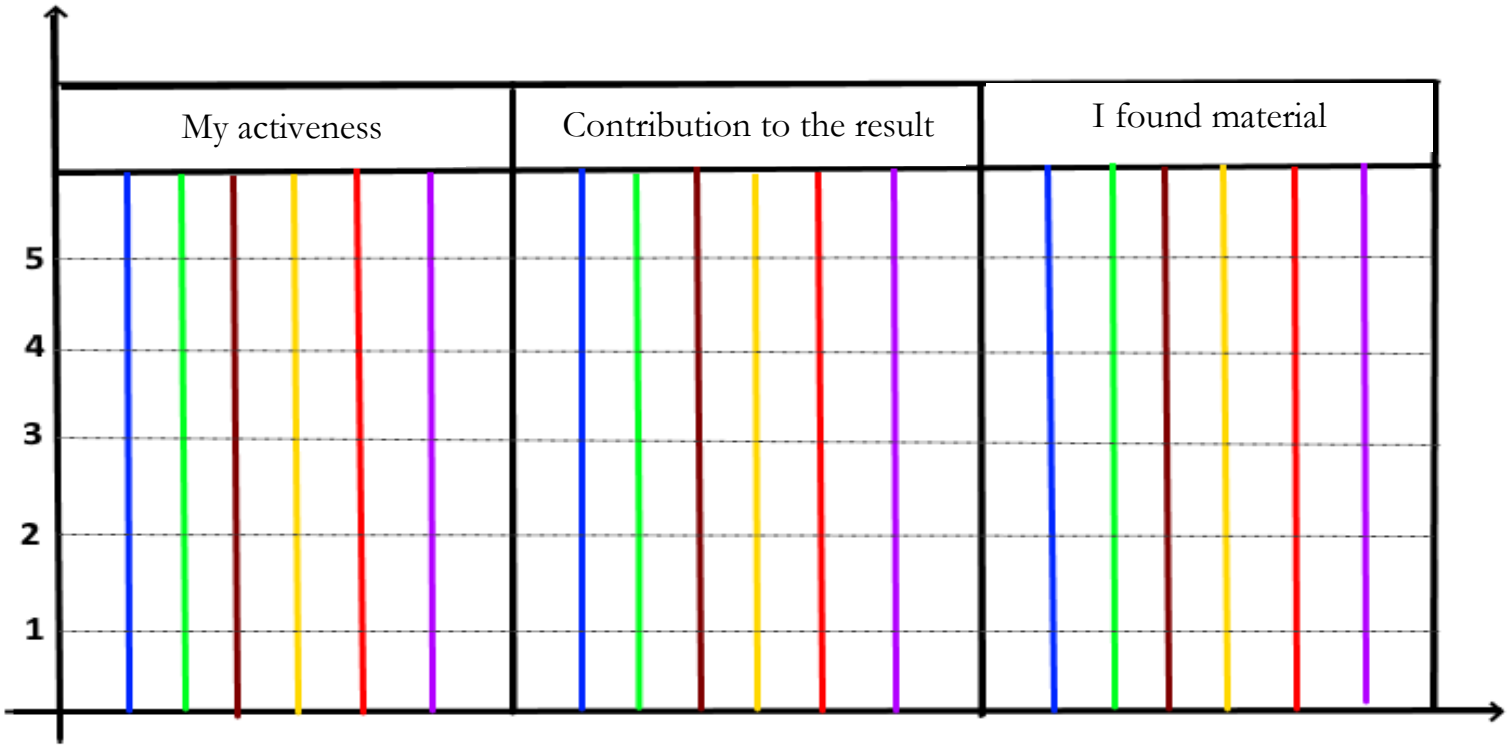
Annex 1 - Recommendations and steps for the evaluation

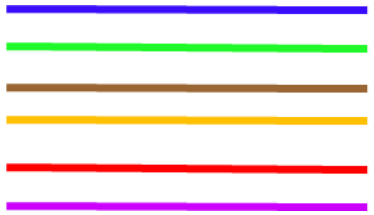
RECOMMENDATIONS FOR STUDY CIRCLE ACTIVITIES AND REQUIREMENTS FOR THEIR ASSESSMENT

1. Revealing the main idea of the text.
2. Purposeful use of additional material
3. Relevance of the article.
4. Concreteness and relevance of presented ideas and thoughts.
5. The validity of the presented ideas.
6. Conclusions and generalisation.
7. Self - assessment (what you learned, how it went, what was difficult, what you liked...)
8. Preparation of the presentation.
9. Communicative expression.
10. Filling in the evaluation sheet for working on „Placemat“
11. Filling in the self-evaluation form of study circle members` activities.
12. Every study circle member fills in the evaluation form „ Target“ with the results from the self-evaluation form with chosen colour in areas 3.1,3.2 and 3.3.
13. In the evaluation form „Target“ areas 3.1, 3.2 ir 3.3 are filled in as follows:
    a. if the assessment of the relevant area is 0 or 1 in the self-evaluation form, a dot of your chosen colour is placed in the pink area;
    b. if the assessment of the relevant area is 2,3 or 4 in the self-evaluation form, a dot of your chosen colour is placed in the green area;
    c. if the assessment of the relevant area is 5 in the self-evaluation form, a dot of your chosen colour is placed in the yellow area.

Annex 2 – Self-evaluation form

SELF-EVALUATION OF GROUP MEMBERS





Write your name and country next to the chosen colour.

Evaluate your competences in the diagram with a dot on your colour line.

Annex 3 - Criteria for evaluation of group work on Placemat

STUDY CIRCLE ACTIVITIES, EVALUATION CRITERIA, THEIR CHARACTERISTICS AND IMPORTANCE

Activity field	Evaluation criteria	Signs of evaluation criteria	Points
1. Activity evaluation according to the „Placemat“ method sheet	1.1. Revealing the main idea of the article	The main idea of the article is revealed accurately and comprehensively.	2
		The main idea of the article is partially revealed.	1
		The main idea of the article is not revealed.	0
	1.2. Purposeful use of additional information (material)	The use of additional information (material) is appropriate and/or sufficient.	2
		The use of additional information (material) is partly appropriate and/or sufficient.	1
		The use of additional information (material) is not appropriate and/or sufficient.	0
	1.3. Disseminating the relevance and usefulness of the article`s information	Adaptability and relevance of the article information (material) is revealed and argumented.	2
		Adaptability and relevance of the article information (material) is revealed, but not argumented. Applicability of the article information is named.	1
		Adaptability and relevance of the article information (material) is not revealed, applicability is not named.	0

Annex 4 - Criteria for presentation evaluation

STUDY CIRCLE ACTIVITIES, EVALUATION CRITERIA, THEIR CHARACTERISTICS AND IMPORTANCE

Activity field	Evaluation criteria	Signs of evaluation criteria	Points
2. Presentation evaluation	2.1. Selection of presentation form, design and implementation of recommendations	The presentation form is chosen according to the article features, design is chosen, recommendations for the presentation are fulfilled.	2
		The presentation form is chosen regardless of the specifics of the article, design is simple, recommendations for the presentation are partly fulfilled.	1
		The presentation form is chosen regardless of the specifics of the article, design is not chosen, recommendations for the presentation are not fulfilled.	0
	2.2. Consistency of presentation content	Presentation content is consistent, logically based.	2
		Presentation content is partly consistent, logically based.	1
		Presentation content is chaotic, unreasonable.	0
	2.3. Communicative expression	Verbal and non-verbal expression of communication with listeners is appropriate, questions are answered specifically and clearly, speech is correct, speech norms are observed.	2
		Speaking does not take into account the communicative situation, presented questions are not answered or are not clearly answered, there is no more than one language error.	1
		Presentation speech is not fluent, specific communicative situation is not taken into account, presented questions are not answered, language errors hinder the understanding of the presentation content.	0

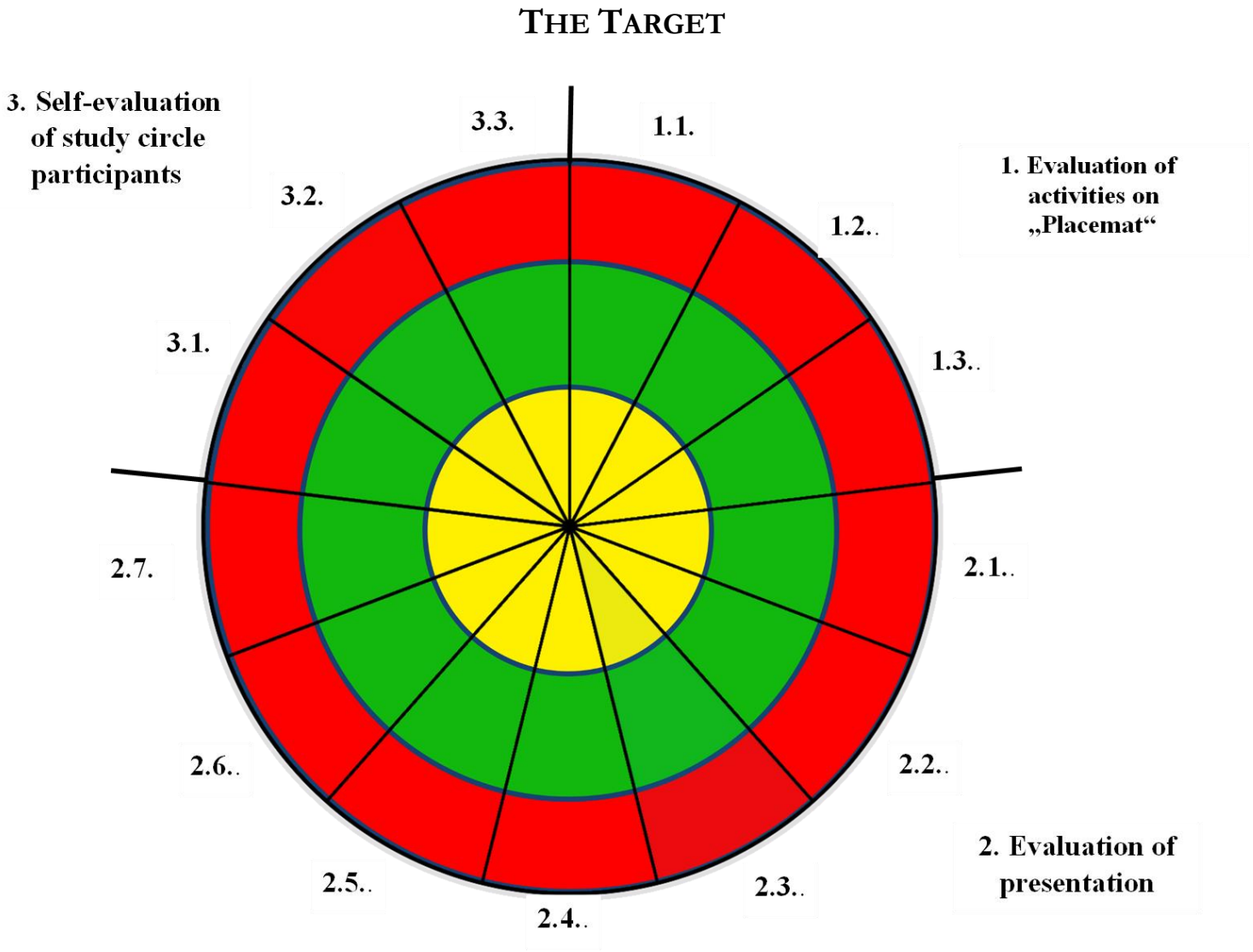
	2.4. Presentation of used information sources	The main information sources and/or means are properly specified and their suitability in the activities is argumented.	2
		The main information sources and/or means are partly properly specified and their suitability in the activities is partly argumented.	1
		Information sources and/or means are not specified.	0
	2.5. Generating creative ideas	Creative ideas are raised and implemented for creating the presentation.	2
		Creative ideas are raised for creating the presentation, but not implemented.	1
		Creative ideas are not raised for creating the presentation.	0
	2.6. Formulation of conclusions	Specific conclusions describing the article are formulated.	2
		Conclusions describing the article are formulated, but they lack concreteness.	1
		Unclear (not specific) little related to the article conclusions are formulated,	0
	2.7. Self – assessment of activity	Students evaluate themselves in a reasoned manner, indicate what they have learned, know where they will apply it.	2
		Students self-evaluate activities, do not indicate accurately what they have learned, do not know the possibilities of application.	1
		Students do not self – evaluate the activities performed, do not know what they have learned, do not understand what and where they will apply it.	0

Annex 5 - Evaluation sheet of study circle activities with criteria

EVALUATION OF STUDY CIRCLE ACTIVITIES

Study circle	Evaluation of activities according to the „Placemat“ method sheet			Evaluation of presentation							**Total score**	Notes, comments
	1.1. Revealing the main idea of the article	1.2. Purposeful use of additional information	1.3. Disseminating the relevance and usefulness of the article`s information	2.1. Selection of presentation form	2.2. Consistency of presentation content	2.3.Communicative expression	2.4. Presentation of used information sources and/or means	2.5. Generating creative ideas	2.6. Formulation of conclusions	2.7. Self – assessment of activity		
Study circle No. 1												
Study circle No. 2												
Study circle No. 3												
Study circle No. 4												

Annex 6 - The Target evaluation form



How to use the "Target"?

Evaluation mark of study circle No.1 is ■

Evaluation mark of study circle No.2 is: ▲

Evaluation mark of study circle No.3 is: ●

Evaluation mark of study circle No.4.is: ♦

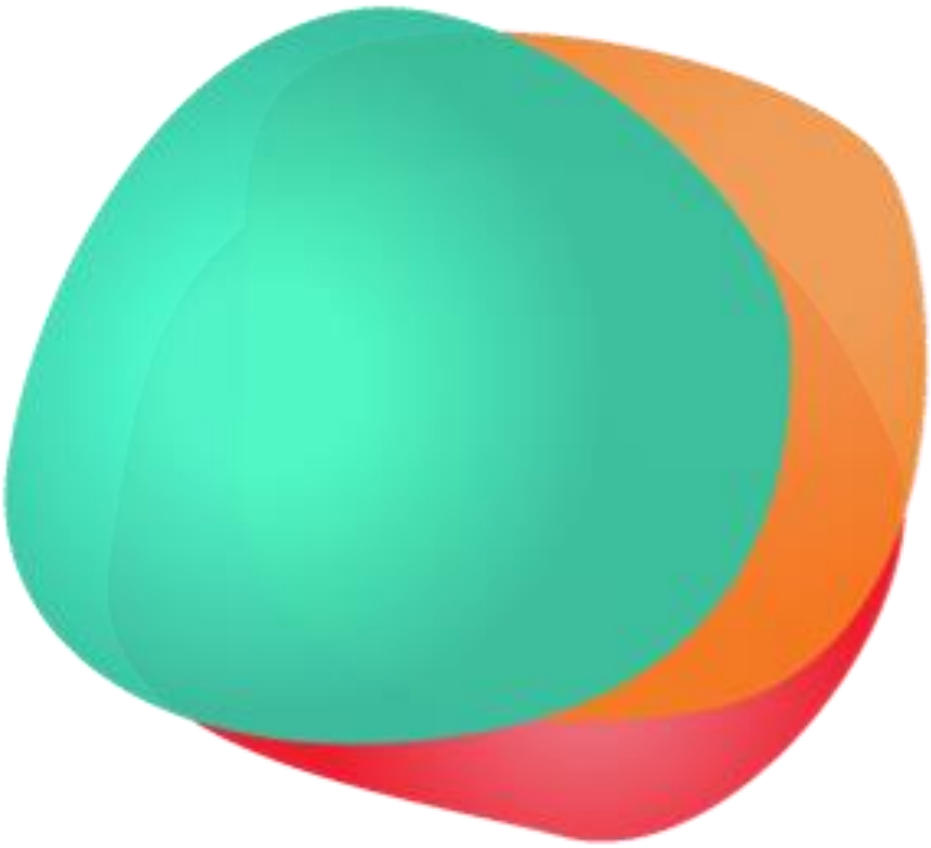
Mark the evaluations with the appropriate point of the study circle as follows:

2 – IN THE YELLOW AREA,

1 – IN THE GREEN AREA,

0 – IN THE RED AREA.

Scientify



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