Learning materials for the implementation of the “Fun with Science” hobby class

This document contains methodical instructions and teaching materials for completing the six-week program of the “Fun with Science” hobby class, which is intended for children who fled the horrors of war to the Czech Republic and Poland from the Russian aggression in Ukraine. The goal is to offer children a meaningful way to spend their free time, using elements of science popularization. The club is open to all children who are interested in science and the world around us, but it is especially suitable for gifted children who are heading for secondary school and university studies.

The aim of the methodological materials is to provide details and recommendations for the implementation of the “Fun with Science” hobby class so that it can be opened to children and offered by various institutions in the Czech Republic, Poland, but also in other countries. All materials are therefore prepared in four language versions - in English, Ukrainian, Czech, and Polish.

The content of the hobby class is very practically focused. Our aim is not only to introduce, describe, and show selected areas of science to the participants of the hobby class, but above all to let the participants independently solve a task, carry out an experiment, think in a discussion with others about interesting questions, etc. An important partial goal of the content of the hobby class is also to support the development of communicative and social skills of the participants, motivate them to have a deep approach to learning, interest in science and technology, and their own creativity in finding unusual solutions and to “think outside the box”.

The methodological materials are intended for lecturers of the “Fun with Science” hobby class as a support tool for the implementation of specific popularization activities. The materials can also be used by teachers who decide to include partial popularization activities in their lessons.

As part of the Future4Refugees project, 2 MOOC courses will be created, in addition to these methodological materials. The target group of the first MOOC course “Fun with science (for young scientists)” is primary and secondary school students. The course contains an extension of the multimedia contents for the activities described in these methodological materials. The MOOC course can be used not only directly during the “Fun with Science” hobby class, but is prepared in such a way that interested parties can go through it individually and completely independently. As part of the “Fun with Science” hobby class, which pupils attend at an educational institution, the MOOC course serves as a platform for drawing

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multimedia content, and specific activities are not carried out by each participant alone, but are included to be carried out as part of joint meetings.

The second MOOC course “Fun with science (for teachers)” is focused on general issues of the effective popularization of science. The course is intended primarily for teachers and lecturers of popularization hobby classs. The “Fun with Science” hobby class, and the specific teaching materials described in this document, are commented here as one of the examples of good practice, as a topic for filling the free time of children who are fleeing from war.

These methodological materials were prepared in 2023.
The range of methodological materials is 23 pages.

The prepared materials include materials for popularization activities, with which it is possible to fill at least six weeks of the “Fun with Science” hobby class. Each week is focused on one basic topic, to which individual activities are linked.

Overview of topics:

1) Man and computer
2) Man and robot
3) Man and smart technologies
4) Man and the press
5) Man and health
6) Man and nature

1. Man and computer

I. The teacher presents: Our topic today is “Man and Computer”. Search the Internet for the following words to find out what they mean and how they relate to our topic:

- Abacus *(SOLUTION: An abacus is a simple mechanical aid to facilitate calculations. It would be an exaggeration to say that it is the earliest predecessor of the computer. Originally, it was a board with stones and columns, later a plate with grooves or a frame with balls on rods. In some cases it was plate, replaced only by marked lines in the sand.)*
- Charles Babbage (*SOLUTION: Charles Babbage (1791-1871) was an English mathematician and inventor who was the first to try to build a programmable machine that could solve complex calculations - in other words, the first computer.*)
- ENIAC (*SOLUTION: ENIAC was the first Turing complete tube computer. It was developed at the University of Pennsylvania, and first launched in 1944. Its creators were John William Mauchly and John Presper Ecker.*)

II. The teacher presents (e.g. as group work): The number of computers continues to increase, their performance is constantly growing, and they are gradually affecting various areas of our lives. Describe how you think the human-computer relationship has evolved from the invention of the first computer to the present day. What effect did computers have and do they have on society? Discuss the advantages and disadvantages of using computers, and how they affect our daily lives. Give examples.

III. The teacher presents: Computers have become an important tool for working with information, from a wide variety of areas and fields. Thanks to this, a number of new scientific disciplines have been created, such as mathematical informatics, bioinformatics, geoinformatics, chemoinformatics, biomedical (medical) informatics, neuroinformatics, etc. What do you think these disciplines deal with? Check your assumptions using the Internet.

IV. The teacher presents: You already know what neuroinformatics deals with. Let’s now take a look at the neuroinformatics laboratory together. Watch the video carefully, and answer the questions:

- How is the track in the laboratory different from classic track models?

- How can this train be controlled, and on what principle does this control work? *(SOLUTION: The train can be controlled using brain waves. The principle of controlling the train consists in using a sensor (Mindwave Mobile device) to record the brain activity of the user, which is*

evaluated in real time by the computer. Based on the measured level of attention, the speed of movement of the model H0 train is then set to the digital track.)

- How can this train control principle be used in everyday life? (*SOLUTION: E.g. for patients with neuromuscular disorders that prevent them from moving and communicating in a normal way. Thanks to the brain-computer interface, they can then operate various devices – e.g. lighting, TV, telephone, etc.*)

- What is the goal of the presented project? (*SOLUTION: Invent a technical solution that will be financially accessible for users.*)

Video: **SCIENCE CURIOSITY: Smart Train - a train controlled by brain waves**

After watching the video, the students answer the above questions, which they were supposed to find answers to during the projection.

IV. The teacher presents: Design an assistance system or device that works on the principle you saw in the video. Your product should help a person with a severe disability in their daily life. Think about who, how, and why your product will help, and then create a presentation for a potential investor in your start-up.

2. Man and robot

I. The teacher asks: People make machines to make their jobs easier and their lives more pleasant. So machines should be our helpers. Can they also become our competitors under certain circumstances? If so, how can they compete with us? Give examples.

II. The teacher presents: Robots represent a specific category of machines that are part of our lives. What exactly is a robot? Create a mind map for the word “robot” and then try to formulate a definition of the term “robot”, based on this map.

(*SUGGESTED SOLUTION: A robot is a programmable device that consists of mechanical and electronic components, and is designed to perform autonomous or controlled activities. Robots are used in various fields, such as industry, healthcare, science, military, and many others. They can be designed to perform specific tasks, such as welding, assembly, or packaging, or for a wider range of tasks, such as navigating through unknown terrain, or driving a vehicle autonomously.*)

III. The teacher presents: Now let’s watch the following video together. Watch it carefully, and answer the questions:

- What does the word “collaborative” mean? (*SOLUTION: co-operative*) The teacher can ask about related words (collaborate/collaborator/collaboration), or whether, and in what context, the pupils have encountered them.

- How does this robot differ from classic industrial robots? (*SOLUTION: Thanks to sensors, it can stop movement if a person is too close - so it is safe to work with, and the robot does not need to have a protective cage around it.)*

- What is AGV? (*SOLUTION: an automatic vehicle – Automated Guided Vehicle*)

- What is an AGV used for? (*SOLUTION: To transport material(s) as part of internal logistics.*)

Video: ***Science Curiosity: Collaborative robot***

After watching the video, the students answer the above questions, which they were supposed to find answers to during the projection.

IV. The teacher presents: Describe the individual stages of the robot’s workflow that you saw in the video. Then discuss how the robot can be taught to distinguish or differentiate between the different colours of individual pucks, and place them correctly on the palette.

(*SOLUTION: The AGV transports the pallet under the robot, the robot takes a picture of it using a camera, and specialized software detects the positions on the pallet with the corresponding colours. The robot then moves over the trays with pucks, which it also takes a picture of. It thereby recognizes the colours of the pucks in the respective containers. Subsequently, it gradually removes the individual pucks and places them correctly on the pallet so that the colours on the pallet and on the puck match. Once the operation is complete, the robot proceeds according to the type of programme selected: Either it empties the pallet again and returns the pucks to the hoppers, or the conveyor sends the pallet to a manual workplace, where it is emptied by a human. The empty pallet then moves to a position where it can be picked up again by the AGV.*)

V. The teacher asks:

- Could a collaborative robot in the form of a robotic hand be used outside of the factory environment? Suggest where you would use it. (*SOLUTION: warehouse, operating room, assistance for the disabled, support for pyrotechnics, restaurants - see e.g. Robot Café in the Museum of Applied Arts in Brno, etc.)*

- What could we use AGVs for in everyday life? (at home, in a restaurant, at the airport...)

VI. The teacher presents: Make your own robotic arm from a suitable kit (e.g. Lego Mindstorms EV3, Lego WeDo, Fischertechnik) or a mechanical hand according to this guide.

VII. Additional materials on the topic:

Science Curiosity: Tabletop factory

Ing. Ondřej SEVERA - Cybernetics

3. Man and smart technology

I. The teacher asks:

- What comes to mind when you think of the term “smart technology”?

Student associations can be collected in a word cloud, e.g. through the applications Slido, Mentimeter, etc., or analogically on a blackboard or large piece of paper.

Based on the collected associations, a definition of the term “smart technology” can be created together by the group as a whole.

(*SUGGESTED SOLUTION: In informatics and technology, smart technologies are defined as innovative systems and devices that are equipped with sensors, processors, communication capabilities, and other functions, thanks to which they are able to interact with users, collect and analyse data, and to adapt to and respond to the surrounding environment. Smart technologies can be part of a wide variety of devices, including smartphones, smart home appliances, automobiles, urban infrastructure, medical devices, and more. Smart technologies have the potential to increase the efficiency and effectiveness of various processes, and make people’s daily lives easier, both in private and at work.*)

II. The teacher presents:

- Divide into two groups and choose one of the following stations: smart city, smart home.

Find out together (in discussions and using the Internet) what the given term means, propose several concrete solutions for your city or household, and at the end present everything to the other group. (This topic can possibly be divided into two teaching units, so that students can also model and show their solutions, e.g. in Minecraft.)

- This is followed by a joint discussion of the presented ideas, supplemented by any other suggestions for improvement.

III. The teacher presents: Now let’s watch the following video together. Watch it carefully, and answer the questions:

- What is the difference between ordinary and conductive thread? (*SOLUTION: Conductive microwires are cut into the conductive thread so that the thread can conduct electricity.*)

- What can conductive threads be used for? (*SOLUTION: heated knitwear, embroidered sensors on clothes, flexible LED diode strips...*)

- Why is it better to use embroidered sensors and buttons than classic electronics in some cases? (*SOLUTION: Embroidered sensors on clothes are not so visible and do not get in the way.*)

Video: Science Curiosity: Smart textiles

After watching the video, the students answer the above questions, which they were supposed to find answers to during the projection.

IV. The teacher presents: Now you know a lot about smart technologies. Now divide into groups and invent a new smart device that could be useful in everyday life. In doing so, consider factors such as user needs, technology capabilities, and the practicality of the design itself. Come up with an advertising slogan for the product you design.

V. The teacher presents: Until your next meeting, track and record how you use smart technologies in your everyday life. We will then evaluate together how these technologies affect your daily life, and whether you are getting any added value from them.

VI. Additional materials on the topic:

Science Curiosity: A fire-fighter's smart suit

Science Curiosity: IOT lab

4. Man and print

I. The teacher presents: Printers of various kinds have become a common part of our lives. There are different types of printers that differ in their features, the technologies used, and the possibilities of use. These are some of the most commonly used printer types: inkjet printer, laser printer, dye sublimation printer, 3D printer, printed electronics printer, thermal printer, mobile printer.

Give them a suitable description. (The teacher will prepare the assignment sheet according to the information in the solution.)

(*SOLUTION:*

1. *Inkjet printer: This type of printer uses liquid inks that are applied to the paper using a print head. Inkjet printers are suitable for printing documents and photos in a home or office environment.*

2. *Laser printer: This type of printer uses laser beams to create an image on the surface of the paper. Laser printers are usually faster and more suitable for printing larger volumes of documents in an office environment.*

3. *Thermal Sublimation Printer: This type of printer uses special inks that are transferred to the surface of materials such as T-shirts or mugs using high temperature. The sublimation thermal transfer printer is often used for printing promotional items.*

4. *3D printer: This type of printer prints three-dimensional objects by successively applying layers of material. 3D printers are increasingly used in the field of industrial design and production, as well as for printing prototypes and manufacturing unique products.*

5. *Printer for the production of printed electronics: This type of printer makes it possible to print electronic circuits directly on the substrate, i.e. on plastic, paper, glass, ceramics, PET foil, etc. Printed electronics are used mainly in the field of industry, e.g. in the production of sensors, RFID chips, displays, and other electronic components.*

6. *Thermal printer: This type of printer uses heat to create an image on the surface of the paper. Thermal printers are often used to print labels, receipts, and other documents.*

7. *Mobile Printer: Designed for on-the-go use, this type of printer allows users to print documents or photos directly from a mobile device such as a Smartphone or tablet.*)

II. The teacher asks: Which of the above printers have you already encountered? Can you imagine what a printer for the production of printed electronics looks like?

III. The teacher presents: Now we will look at one such special printer for the production of printed electronics. Watch the video carefully, and answer the following questions:

- What materials are used in printing? (*SOLUTION: Materials based on nanostructures are mostly used*.)

- What is the name of the presented printer and why? (*SOLUTION: The printer is called an Aerosol Jet printer - it uses aerosols when printing*.)

- How does a printer work? Describe the printing process. (*SOLUTION: Nanoparticle ink is made into an aerosol by mixing nitrogen and nanoparticle liquid material. This aerosol goes into the nozzle, where the nitrogen stream focuses the aerosol beam and applies it to the selected substrate.*)

- How thick layers and lines can be printed on this printer? (*SOLUTION: Very thin layers and very narrow lines can be printed - line width from 10 micrometers, layer thickness from 10 nanometres.*)

Video: Science Curiosity: Printed electronics

After watching the video, the students answer the above questions, which they were supposed to find answers to during the projection.

IV. The teacher presents: Two important terms were mentioned in the video, namely nanoparticles and aerosol. What is the meaning of these words? (*SOLUTION: nanoparticles = objects whose three outer dimensions are on the nanoscale - the scientific prefix "nano" is short for one billionth, i.e. 10^9. The word comes from the Greek "nanos", which literally means "dwarf"; aerosol = a mixture of solid or liquid particles in the form of a suspension in a gaseous medium. – e.g. clouds*)

V. The teacher presents: Now we will look at the issue of printed electronics production in more detail. Here is a description of the individual steps of the printed electronics manufacturing process. Arrange them chronologically, according to how you think they follow each other. *(Note: The teacher will divide the description of the individual steps from the solution below into separate cards, which the students will then have to sort. It will only show the description on the cards, without the introduction/naming of the step.)*

VI. The teacher presents: We already know how printed electronics are manufactured. Go through all the stages again, and name them in a word or two. This creates a clear list of individual steps.

(*SOLUTION: In the production of printed electronics, electronic circuits are created directly on the surface of the substrate using special printing technology and materials. Production takes place in the following steps:*

1. *Circuit design: First, an electronic circuit design is created to be printed. This design is usually created using special CAD (computer-aided design) software.*

2. *Preparation of materials: Special inks or pastes are used to print printed electronics that contain conductive materials, such as silver or copper. These materials are mixed with a solvent, and printed using a special print head.*

3. *Printing: The created design is uploaded to the printer and printed directly on the surface of the substrate. Printing is performed by successively applying layers of ink or paste.*

4. *Baking: After printing, the substrate with the printed circuit is exposed to a baking process that serves to cure the printed ink or paste. This process allows conductive materials to join together to form a functional electronic circuit.*

5. *Testing: After the printing and baking are complete, the circuit is functionally tested to verify that it is working properly.*)

VII. The teacher asks: We already know quite a lot about printed electronics. What do you think are its advantages?

(*SUGGESTED SOLUTION:*

1. *Flexibility – One of the main advantages of printed electronics is its flexibility. This means that it can be printed on a wide variety of materials, such as paper, metal foils, textiles, or even flexible materials. This enables the production of new types of electronic devices, such as smart clothing or flexible sensors.*

2. *Transparency – By using transparent materials, printed electronic components can be made to be transparent. This enables their use in various applications, such as transparent displays, sensors, or photovoltaic cells.*

3. *Reduction of production costs – Printing electronic circuits on substrates instead of traditional manufacturing processes, such as casting or milling, can reduce manufacturing*

costs. This allows for the production of cheaper electronic devices, and allows even small companies to produce electronic products.

4. Speed – Printing electronic circuits is a very fast process. Printed electronics printers are capable of printing tens to hundreds of metres of electronic circuits per hour on average, meaning that larger quantities can be produced in a short time.

5. Design flexibility – Printing electronic circuits allows designers great flexibility in designing new products. It is possible to quickly prototype and test new ideas, which can lead to improved quality and innovation.

6. *Easy integration – Printed electronics are easily integrated with other electronic components, such as sensors, microchips, and batteries, enabling the creation of complex electronic systems.*

7. *Environmental friendliness – Electronic circuit printing uses far less materials and energy than traditional manufacturing processes, meaning it is more environmentally friendly.*)

VIII. The teacher asks: As it turns out, printed electronics have a number of advantages, and can be used in many different areas. Where do you think we can meet such printed electronics?

(*SUGGESTED SOLUTION:*

1. Healthcare: Printed sensors can be used to monitor patient vital signs and improve diagnostics. They can also be used to create new types of low-cost and customizable medical devices.

2. Manufacturing: Printed sensors and circuits can be used to improve the manufacturing process, monitor the condition of machines, and maintain them.

3. Sports activities: Printed sensors and circuits can be used to monitor the performance of athletes, such as heart rate, blood pressure, and other parameters.

4. Home appliances: Printed circuits can be used in home appliances, such as washing machines, refrigerators, coffee makers, etc. to make them smart and energy efficient.

5. Automotive: Printed sensors and circuits can be used to monitor the condition of vehicles, and for safety systems, such as airbags and braking systems.)

IX. The teacher presents: Design a product that uses printed electronics. Subsequently, play the role of salesman and convince the potential customer of the benefits of your product.

X. Additional materials on the topic:

Science Curiosity: Clean spaces (demonstration of printing and baking of printed electronics in a laboratory with a special regimen)

Another possible thematic unit: 3D printing

3D printing is a technology that makes it possible to create three-dimensional objects from a digital model by successively applying material, layer by layer. Here are 10 ways 3D printing can be used:

1. Industrial production: 3D printing enables faster and cheaper production of prototypes and parts. It is also possible to create complex geometric shapes that would not be possible to produce with other technologies.

2. Architecture: 3D printing can be used to create building models, for urban planning, and other architectural designs.

3. Healthcare: 3D printing can be used to create models of human organs, bones, and tissues for diagnosis and surgical planning.

4. Space exploration: 3D printing can be used to make spare parts for spacecraft and probes.

5. Education: 3D printing can be used to create interactive and visual aids for teaching.

6. Design: 3D printing allows creators to create unique and complex shapes for products, such as bracelets, rings, and other accessories.

7. Production of toy figures: 3D printing allows the creation of custom toy figures and miniatures for board games and RPG games.

8. Jewellery Making: 3D printing allows creators to create unique jewellery, like earrings, bracelets, and necklaces.

9. Construction: 3D printing can be used to produce building parts and panels for building and bridge structures.

10. Food industry: 3D printing can be used to create unique shapes and designs for desserts, confectionery, and other foods.

See the video for another possibility of using 3D printing:

Science Curiosity: Indiana Jones and the Spear of Destiny at UWB

Is 3D Printed Food the Future? (you can turn on subtitles + automatic translation into the target language)

5. Man and health

I. The teacher asks: Today we will focus on the issue of health and saving lives. Have you ever had to provide first aid? Or, on the contrary, did you find yourself in the role of the one who needed first aid? If so, share your experience with us.

II. The teacher asks: Have you ever had a chance to look inside an ambulance? Or even to ride in one?

III. The teacher presents: Right now we're going to take a look at one ambulance. Watch the video and explain the following terms:

- skiagraph (*SOLUTION: A skiagraph is a device that uses X-rays to image the structures of the human body.*)
- resuscitation (*SOLUTION: Resuscitation is reviving/restoring vital functions.*)
- exitus (*SOLUTION: Exitus means death.*)
- simulation (*SOLUTION: In our context, simulation is used in the sense of creating model situations.*)

Video: Science Curiosity: With paramedics in an ambulance

IV. The teacher presents: In the video, you had the opportunity to see the resuscitation of the patient. Describe how the rescuers performed it.

V. The teacher asks: What would you do if you found yourself in the role of a rescuer, but had no special equipment at your disposal? Do you know how to provide first aid for respiratory/cardiac arrest?

VI. The teacher presents: Let's create a model situation. One participant will simulate a person in cardiac arrest, the others will try to invent and demonstrate the correct rescue procedure. We will write down the individual points of the rescue procedure together.

(*SOLUTION:*

1. Safety

We will make sure that the situation we are in is safe, and that we ourselves will not be in danger of death or risk to health during the rescue.

2. Contact

We address the disabled person loudly, shake him/her, and if he/she does not respond, we find out what his/her current condition is. We place the affected person on his/her back, place one hand on his/her forehead, the other under his/her chin and tilt his/her head with a gentle movement (we do not support the neck with anything). We bring our ear to the affected person's mouth, at the same time we monitor the movements of the chest, and thereby find out if he/she is breathing or not. If he/she is breathing, we continue to monitor his/her condition, and call the emergency services. If he/she is not breathing, or breathing only with great difficulty (e.g. gasping for breath), we call the emergency services, and we have to start resuscitation.

3. Emergency line

We call the emergency line (in the Czech Republic phone No. 155), report the location, and describe the condition of the affected person. It is ideal to switch the phone to speakerphone so that you don't have to hold it, and have both hands free during the rescue.

4. Resuscitation

We begin the heart massage: We place our hands with the edge of the palm on the centre of the affected person's chest, we can intertwine our fingers, we bend our hands at the elbows, and with our entire body weight we press the chest at a regular pace, approx. 5 cm deep.

VII. The teacher asks: At what pace do you need to compress the chest for heart massage to be effective? Watch the following video to find out. Then summarize in your own words why it is important to perform heart massage at this particular pace, and to compress the chest deeply enough.)

Video: **CPR in Action | A 3D look inside the body** (subtitles and automatic translation into the target language can be turned on in the video settings)

(*SOLUTION: The ideal frequency of chest compressions during resuscitation is 100-120 chest compressions per minute, i.e. 2x per second. The heart massage must be brisk and intense so that it is possible to get blood, and with it oxygen, to the affected brain. If the brain were to remain without oxygen for 10 minutes, it would be irreversibly damaged.*)

VIII. The teacher presents: Now you already theoretically know at what pace you need to compress the chest during resuscitation. Try clapping fast like this!

And now we'll check if you hit the mark. You should do chest compressions during CPR to every beat of this song (note its telling title): Bee Gees - Stayin' Alive

IX. The teacher presents: Heart massage is physically very demanding. If we are not alone in the rescue, it is therefore ideal to reach out to another person or persons who will take turns being the rescuer during the resuscitation. If there are more rescuers, one of them can also try to get an AED nearby to help us with resuscitation. Learn what an AED is, and search the Internet to see if there is one near you.

(*SOLUTION: AED is short for "Automated External Defibrillator". Special databases of all publicly available defibrillators can be found on the Internet - e.g. AED map in the Czech Republic or the AED map in Poland. The location of defibrillators is also recorded on mapy.cz - just enter "AEG city name".*)

X. The teacher presents: Now we will create a model situation and try out how a rescue operation might look in real life.

Role playing:

- Role: disabled person, rescuing person(s), operator on the emergency line, paramedics in the ambulance, passers-by/audience (someone is filming everything on their cell phone, someone is getting in the way, someone is behaving hysterically, someone is giving "good" advice...), railway staff

- Situation: We are at the station. An elderly lady with a cane leaves the platform. On the stairs, a passer-by accidentally shoves a backpack into her, the lady falls down the stairs, and remains lying on the ground. She is not breathing, and her leg is clearly broken.

(SOLUTION: Approach the injured person, check her condition, call an ambulance and start with classic resuscitation. There is usually an AED available at the station. Get it and use it. Do not treat the broken leg, the priority is cardiac arrest, which threatens the life of the injured person.

XI. The topic can be supplemented with a discussion on the ethics of resuscitation.

XII. Additional materials on the topic:

Science Curiosity: Dr. Lukáš Friedl, Ph.D, Mgr. - What we can read from the bones

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6. Man and nature

I. The teacher presents: You must be wondering what our topic will be today. Read the following short text, fill in the missing words, and find out what we will talk about today.

chaotic – mathematical – failed – self-similarity – complex – turbulence – arrangement

One of the most complex and interesting phenomena in nature is _____. You may be surprised that despite decades of research, scientists have still _____ to describe this phenomenon perfectly. There are still many unanswered questions.

From the perspective of _____ modelling, turbulence is often described as _____ movement, but at the same time, there are known cases where it is possible to find a certain kind of order or _____ in turbulent flows.

There are even theories that try to find an ordered pattern in turbulence, such as _____ theory, which describes that similar patterns and structures repeat themselves at different levels of turbulence.

It is therefore possible that although turbulent flow appears chaotic at first glance, it may actually be so _____ that we are unable to recognize its order.

(*SOLUTION: One of the most complex and interesting phenomena in nature is turbulence. You may be surprised to learn that despite decades of research and attempts, scientists have failed to perfectly describe this phenomenon. There are still many unanswered questions.*

From the point of view of mathematical modelling, turbulence is often described as a chaotic movement, but at the same time there are known cases where it is possible to find a certain kind of order or arrangement in turbulent flows.

There are even theories that try to find an ordered pattern in turbulence, such as self-similarity theory, which describes that similar patterns and structures repeat themselves at different levels of turbulence.

Therefore, it is possible that although turbulent flow appears chaotic to us at first glance, it may actually "only" be so complex that we are unable to recognize its order.)

II. The teacher asks: What do you now know about turbulence? Summarize the information from the previous text.

III. The teacher presents: Let's take a closer look at turbulence. Let's carry out a simple experiment.

Experiment: Visualization of turbulence

Variant 1

Aids:

- Transparent container with water
- Dye (e.g. liquid food colouring)
- Salt
- Immersion blender or propeller

Procedure:

1. Fill the container with water.

2. Add a few drops of food colouring and salt to the water. Thanks to the salt, the water will gain more viscosity, as a result of which the turbulence will be more visible.

3. Turn on the blender or propeller and place it in the container of water.

4. Turbulence should form after a short time. Watch how it changes, depending on the speed or direction of mixing.

Variant 2

Aids:

- Transparent container with water
- Mica glitter
- Stirring stick

Procedure:

5. Fill the container with water.

6. Add mica glitter to make the liquid a thicker consistency.

7. Gradually try mixing the liquid in different directions and at different speeds, and watch how the turbulence forms and transforms.

8. Tip: Try putting an object in the container that the liquid will flow around, and see if it affects the appearance of the turbulence.

Evaluation:

Thanks to this experiment, students should understand how turbulence is created, and how it behaves. After conducting the experiment, discuss with the students what happened in the experiment. You can ask them what caused the turbulence, and what are its characteristics.

(*SOLUTION: In response to the question of what caused the turbulence, students should state that turbulence is caused by a violation of the uniform flow of fluids, for example, when the fluid passes over or around an obstacle, or when the velocity of the flow changes. Turbulence manifests itself as a vortex of water associated with the random movement of particles in the fluid, and the formation of other vortices of different sizes.*)

IV. The teacher asks: We already know how turbulence arises and what it looks like. In the experiment, we were the originators of it. Can we also observe turbulence in nature? If you think so, please provide specific examples.

(*SOLUTION: Turbulence occurs in many different areas of nature, be it the atmosphere, oceans, rivers, or different types of flowing fluids. A few examples:*

1. *Atmospheric turbulence: When flying in an airplane, you can feel turbulence as the plane moves through areas of irregular air currents. This turbulence can be caused by many factors, including uneven heating of the Earth's surface, air movement over mountains or over the ocean, or wind. Another example of atmospheric turbulent flow can be a tornado. A tornado is formed due to the instability of the atmosphere and a significant difference between the temperature and humidity in the air, which leads to the formation of strong vortices. These eddies interact and deform, creating the highly chaotic flow pattern characteristic of turbulence.*

2. *Ocean turbulence: Ocean currents are very complex and dynamic, and involve many different types of turbulence. For example, waves on the surface of the ocean are the result of turbulence which is caused by wind and water movement.*

3. *River turbulence: Water flowing through a river bed can be affected by many factors, such as the unevenness of the bottom, various obstacles, temperature differences, and many other factors. These factors can cause turbulent flow, and subsequently create eddies and rapids.*)

V. The teacher asks: Do you think turbulence can be measured? If so, how would you measure it? Let's see how turbulence is measured by scientists in specialized laboratories. Watch the video carefully, and try to answer the following questions:

- What can be used to measure turbulence? (*SOLUTION: Using a laser.*)

- What does the word "monochromatic" mean in relation to lasers? (*SOLUTION: It has one colour. Generally, the word "monochromatic" is used in contexts involving waves and colours to mean that the wave or light contains only one wavelength or frequency.*)

Video: **Science Curiosity: The secret of turbulence**

After watching the video, the students answer the above questions, which they were supposed to find answers to during the projection.

VI. The teacher asks: Why do you think it is important to study and measure turbulence? Break into groups and try to come up with examples of where the results of turbulence research can be used.

(*SOLUTION: Turbulence research has wide applications in various fields such as:*

1. Aerospace: Turbulence research is important for improving the aerodynamics of aircraft and spacecraft, which can lead to reduced fuel consumption and increased flight safety.

2. Water transport: Turbulence also has a great influence on the hydrodynamics of ships and vessels, and is therefore important for the optimization of maritime transport.

3. Construction: Turbulence research is also used in the design of bridges, skyscrapers, and other tall buildings where wind flow can cause large turbulence.

4. Meteorology: Turbulence has a significant impact on weather and climate, and is therefore important to study for a better understanding of atmospheric conditions.

5. Pharmacology: Turbulence is also used in the field of pharmacy, where it is used, for example, in the design of optimized reactors for drug synthesis.

Turbulence research therefore finds application in many areas, and helps in the optimization of various technologies.)

VII. Additional materials on the topic:

Experiment: Sugar and soap as fuels?