June 2023

STEAMTeach

Science | Technology | Engineering | Arts | Mathematics

Project-Based Learning: Physics and Music

Co-funded by the Erasmus+ Programme of the European Union

PROJECT

PROJECT ACRONYM	STEAMTeach
PROJECT TITLE	STEAM Education for Teaching Professionalism
PROJECT REFERENCE	2020-1-ES01-KA201-082102
START DATE	1st October 2020
KEY ACTION	Cooperation for innovation and the exchange of good practices
ACTION TYPE	Strategic Partnerships for school education

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Project-Based Learning: Physics and Music	
Author	Dr. OLÁH Éva Mária
STEAM areas	Physics, math, design, music, biology, technology
Cross-cultural connections	Musical styles, crafting and playing musical instruments, affinity for music
Summary	
Subject	Physics
Topic	Acoustics, astronomy, particle physics
Age of students	Age 6-20 years
Project time	8 x 45 minutes
Number of participants	15-20 students
Online teaching material	Oláh Éva Mária: A mikrovilág zenéje [1] Oláh Éva: Zenéljünk fizikául vagy fizikázzunk zenéül [2] Kepler: Harmonices mundi [3] **1** Kepler and the Music of the Spheres [4]
Offline teaching material	Oláh Éva, A mikrovilág zenéje, avagy játék a húrokkal, Juhász A., Tél T. (szerk.), A fizika, matematika és művészet találkozása az oktatásban, kutatásban, Budapest (2013), ISBN 978963-284-346-9, pp. 141-146. Részecskefizika tanítása középiskolában, Disszertáció benyújtásának az éve: 2018, Védés éve: 2018. Megjelenés, fokozatszerzés éve: 2018. DOI: 10. 15476/ELTE.2018.127 (PhD), III. rész (A mikrovilág megismertetése zenei analógiákkal)

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	Dr. Nagy Anett, hangszerek a „semmiből”, NUKLEON, III. évf. (2010) 56	
21st-century competences	• Critical thinking • Creativity • Collaboration • Communication • Technology literacy • Flexibility • Leadership • Initiative • Productivity	
Learning objectives	Acquiring discipline-related knowledge, in-depth understanding of topic (acoustics, astronomy), assisting the formation of learning communities, developing manual skills, developing abstract thinking skills, playful learning	
Project Plan		
	Procedure	**Time**
Discuss questions	What does the term music of the spheres mean? How old are the earliest musical instruments? Do you need to understand basic mathematics to play music? Why some people have an ear for music while others do not? Which organs assist hearing? Can physicists play musical instruments? What are high and low sounds? Which animals have the best hearing? Does our hearing range change with age? What is music? How do celestial bodies move? Particle physics or string theory? What are the so-called standing waves?	35 minutes

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	What is the difference between the so-called geocentric and heliocentric model of the universe? Do planets produce sound while they are moving? If they did, would it be possible to hear that sound in space? Does pitch depend on the distance from the Sun? Does frequency range depend on the shape of the elliptic orbit?	
 Brainstorming	Collecting students' ideas Whole-class discussion following group work. Incorporating ideas and innovations into the project.	10 minutes
Prepare	Collecting tools (straws, pliers, paperboard cores, jars, Coke bottles, wine glasses, plastic tubes, PET bottles, coloured paper sheets, scissors, glue, coloured felt tip pens, rulers, strings, wooden spoons, balloons, tins, wooden laths, drain hoses) Crafting "instruments" Drawing rainbow sheets Selecting musical pieces	45 minutes
 Demonstrate	• Sound generator for "audiometry" • Kepler: The Harmony of the Worlds • Kepler's laws • Solar system model • Relationship between speed and frequency Doppler effect • Musical drain hoses By using musical analogies, this section aims to demonstrate that the planets of the Solar System move according to Kepler's laws. The planets' distance from the Sun, the size of their orbit, their eccentricity and the	3 x 45 minutes

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	resulting change in speed all define what sounds may be assigned to their movement. Thus, familiarity with acoustics helps one better understand and discover the amazing system to which our planet belongs. As a starting point, we take a drain hose, a common household fitting to demonstrate how pitch changes depending on how fast or slow we turn it around manually. Higher speed comes with a higher frequency, which, in turn, produces a higher sound. The planets of the Solar System, except for Venus, directly revolve around the same focus i.e. the Sun moving around elliptical orbits, each of which deviates from a perfect circle to a different extent, thus their distance from the Sun varies. At the same time, the gravitational force planets are exposed to also varies which is compensated by their higher or lower speed. This causes our planets to make different "sounds" while orbiting the Sun. Students verify the correlations between frequency and pitch by playing the various musical instruments they craft. Soda bottles filled with varying amounts of water and plastic tubes of differing length can make a sound when we blow into them or hit them respectively while measuring the length of the water and air columns we can determine wavelength and frequency. These art-related activities that are directly performed by students offer them an experimental and more enjoyable learning process and thus they leave class having a longer lasting knowledge. • **Introduction of elementary particles, supersymmetric strings** Watch a video and have a follow-up discussion.	

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	• **Demonstration of differences between longitudinal and transverse waves using a “straw” wave machine** Place straws at right angles on a duct tape at equal distance from each other. For better results, attach balls made of dough to the tips of the straws to make the cyclic process last longer. • **Wavelengths and frequency of musical instruments** $c = \lambda \cdot f$ (where „c” is the speed of the sound wave within a given medium, „λ” is the length of the sound wave and „f” denotes frequency. Even relying on only basic mathematical skills, one can recognize that wavelength is inversely proportional to frequency. In practice, this means that the longer the wavelength (longer columns of water and air) the lower sound it makes. • **Demonstration of standing waves on a guitar** Demonstration of standing waves on a guitar producing partials and overtones. In the case of wind instruments, we can change soundwaves and thus frequency by closing the holes on the instrument. • **Musical tubes** Saw plastic tubes at various points to get pieces of differing length according to figures in the attached table. Chisel the ends for a smooth surface. Then mark each tube with the same colour as the colour of its corresponding note in the so-called rainbow sheet. By slapping the tubes to your palms, produce sounds of music caused by the vibration of the air columns in the tubes. • **Xylophone made of paperboard cores**	

	Cut paperboard cores of tinfoil rolls into pieces of varying length. Then attach them to each other with a string, Use wooden spoons as drum sticks to hit them to see how we make them produce sounds by vibrating air columns. • **Jar instrument** Collect jars of various sizes though the most suitable are the ones with a cubic capacity of 1 litre. Use a digital tuner to mark the height of water column in each jar with a coloured stripe according to the colour code for notes used in the previous task. Then use a wooden spoon to vibrate the water columns and thus produce a sound by hitting the jar. • **PET bottle instrument** Produce sounds of music by hitting bottles that contain water columns of different length. Again, hitting them causes the water to vibrate and thus makes a sound. • **Musical Coke bottle** Fill traditional plastic Coke bottles with water. Based on the given colour code, mark the top of the water column with slips of coloured paper. The bottles thus marked may be emptied and used again to make tuning easier. • **Pipe organ from glasses** Choose appropriate wine glasses of different sizes and shapes. Fill the glasses with water up to a given height. Determine the height of the water column in each glass by using an online tuner to denote various sounds. Wet your finger and gently rub it around along the top of the glass. From time to time, you finger gets stuck a bit or slips creating uneven friction which causes the water column to vibrate.	

	• **Straw whistle** Flatten plastic straws with pliers to make a whistle. Shape the ends of the straws as demonstrated in the video specified in the Appendix. Blow the whistle and then start cutting pieces off with a pair of scissors to hear the different sounds you get depending the length of the straw. Once again, you produce sound by vibrating the air and observe the shorter the straw (decreasing soundwave), the higher the pitch (higher frequency). • **Tin drums** Cut off the top of a can, chisel it for a smooth surface and attach a rubber sheet cut out from a balloon on the hole with a string. Use a wooden stick to vibrate the "membrane" which in turn vibrates the air and thus a sound is produced. This tin drum cannot be tuned but it can be used a rhythm instrument accompanying the rest of the instruments.	
Predict	We cannot hear in vacuum Waves: reflection and interference Planets do not make sounds due to the lack of atmosphere Difference between the revolution and rotation of celestial bodies	15 minutes
Plan	Using household waste, students make their own instruments. Playing these instruments they explore specific areas of physics in a more relevant and expressive way	30 minutes
Explore	The focus of the project is to have students chart the laws of physics. Their exploration based on hands-on, minds-on learning leads to a deeper and more lasting knowledge.	15 minutes
	Students compare their results with their preliminary assumptions and formulate their experience.	15 minutes

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Record		
Reflect	Why do assumptions and experience differ? Why don’t your instruments make a sound? What could you make a better instrument?	15 minutes
Presentation	Students perform simple musical pieces playing the instruments they have crafted, they explain their principles of operation.	45 minutes
Product	Various musical instruments Rainbow sheets Docx Videos	
Re-design	Find the faults in design that hinder your instrument to make a (proper) sound	
	Stations	
Science station	Science includes thinking, observation and experiments. It is important to voice assumptions and then share experience. Matching sounds and the movement of planets. Tools Musical instruments, tablets, PC, notebooks, pens	
Research station	**Physics** Introduction into and understanding of Kepler’ laws of planetary motion. Becoming familiar with the dynamics of circular motion and the force of gravitation. The essence of gravitation.	

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<td></td>
<td colspan="2">Discovering the basic principles of acoustics, defining the correlation between frequency and wavelength.
Exploring correlations through independent experiments
Making sounds, observing tones and pitch
Becoming familiar with specific concepts relating to the science of waves
Tools
Instruments, books, tablets, computers, waves-model</td>
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<td>
Technology station</td>
<td>Electronic technology
• Computers
• Tablets
• Smartphones
• Smartboards
• Digital camera</td>
<td>Non-electronic technology
• Straws
• Pliers
• Paperboard cores
• Various bottled
• Glasses
• Plastic tubes
• PET bottled
• Dough
• Coloured paper sheets
• Scissors
• Glue
• Coloured felt tip pens
• Rulers
• String
• Wooden spoons
• Balloons
• Tins
• Wooden laths
• Drain hose</td>
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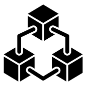 Engineering station	**Engineering tools and materials** • Pliers • saw • Markers, pens • Ruler • Scissors • File	
 Art and Design station	**Art and design supplies** **Music** Recording sounds on staves Recognizing intervals Playing instruments Tools • Glue • Scissors • Coloured paper sheets	
 Maths station	**Maths tools** Introduction into fractions, dividing length into equal parts, calculating amounts based on direct and inverse proportionality. Tools • Calculators • Rulers	
 Recording station	• pens • notebooks	

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Experiences	At the end of the project, joint assessment of experience, discussion of further ideas and future plans Recognizing links between specific disciplines, formulating correlations.	
Appendix	Video [1] https://www.youtube.com/watch?v=Sn9UtxpMZcA&t=1260s [2] https://www.youtube.com/watch?v=g0t0ZPIyv5g&t=3s [3] https://www.youtube.com/watch?v=WihmsRinpQU [4] Kepler and the Music of the Spheres - YouTube [5] Street artist playing Hallelujah with crystal glasses Street artist playing Hallelujah with crystal glasses - YouTube **2 [6] The straw trick - How to make a whistle straw** The straw trick - How to make a whistle straw - Easy and simple - YouTube Links [7] https://nuklearis.hu/sites/default/files/nukleon/Nukleon_3_1_56_Nagy.pdf **Discussion** Discussion of assumptions and questions, their verification or rebuttal **Group work** Assigning preparatory tasks to groups 2-3 Assigning individual tasks to group members	

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	Crafting the product in small groups (instrument, word document, PPT, etc.) **Experiments** Higher speed results in higher pitch By vibrating the air, we can make a sound Sounds are produced according to the laws of mathematics.