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EXERCISE 1: Harnessing Wind Power

DESCRIPTION

Exploring the intricacies of wind energy holds immense importance in our quest for sustainable and renewable energy sources. By delving into this topic, we gain insights into the vast potential of harnessing wind power and its pivotal role in shaping the future of clean energy.

Understanding the historical context, current applications, and future projections of wind energy equips us with knowledge essential for addressing global energy challenges and fostering a more environmentally conscious world. This exploration underscores the significance of embracing innovative solutions that blend technology, environmental considerations, and scientific advancements to create a sustainable and harmonious relationship with our planet.

DIDACTIC-METHODICAL COMMENTARY

Harnessing Wind Power offers an engaging platform for students to delve into the realm of renewable energy and environmental sustainability. This topic encourages an interdisciplinary approach, integrating concepts from physics, environmental science, and engineering. By exploring the principles behind wind energy conversion and the design of wind turbines, students can develop a deeper understanding of the technological advancements driving the renewable energy sector.

The didactic approach involves a combination of theoretical learning and hands-on experimentation. Students can explore the physics of wind energy through interactive simulations and practical activities. Additionally, field trips to wind farms or virtual tours can provide real-world context and insights into the practical applications of harnessing wind power. Collaborative projects and group discussions further enhance learning outcomes, fostering teamwork and critical thinking skills. Overall, this topic empowers students to become informed global citizens, equipped to address pressing environmental challenges and advocate for sustainable energy solutions.

EXAMPLE RESOURCES FOR EXPERIMENTAL WORK IN STEM ENVIRONMENT ON THE TOPIC " HARNESSING WIND POWER":

Resource 1: *Wind Turbine Model Kit. Build a small-scale wind turbine model to understand the basic principles of wind energy conversion.*

Resource 2: *Wind Speed Anemometer Kit.Construct an anemometer device to measure wind speed and explore its role in assessing wind energy potential.*

Resource 3: *Virtual Wind Farm Simulation Software. Explore virtual wind farms to understand turbine placement and optimize energy production strategies.*

SAMPLE INVESTIGATIVE QUESTIONS ON THE TOPIC INTENDED FOR PROJECT ACTIVITIES IN STEM ENVIRONMENT:

1. How do wind turbine designs vary for different wind conditions and energy output requirements?
2. What are the environmental impacts associated with the installation and operation of onshore and offshore wind farms?
3. How does the integration of wind power into the energy grid affect overall grid stability and reliability?
4. What are the economic considerations in developing and maintaining wind energy projects compared to traditional fossil fuel-based power plants?
5. How do advancements in materials science contribute to the development of more efficient and durable wind turbine components?
6. What are the challenges and opportunities for community-owned wind energy projects in promoting local renewable energy production?
7. How can wind energy be combined with other renewable energy sources, such as solar and hydroelectric power, to create hybrid energy systems?
8. What are the potential impacts of climate change on future wind patterns and wind energy generation?
9. How can wind energy technologies be adapted and scaled for use in developing countries and remote regions with limited access to traditional energy sources?
10. What policies and regulations are necessary to promote the widespread adoption of wind energy and accelerate the transition to a low-carbon energy future?

Resource 1

WIND TURBINE MODEL KIT

BRIEF INFORMATION ABOUT THE LEARNING RESOURCE

Subjects	Chemistry, Physics, Biology, Information Technologies
Age	Students
Time for execution	2 hours

This learning resource is a hands-on educational kit designed to help students understand the principles of wind energy and the functionality of wind turbines. The kit includes all the necessary materials and instructions for students to build their own working model of a wind turbine. Through assembly and experimentation, students will learn about the components of a wind turbine, how wind energy is converted into electricity, and the factors that affect turbine performance. The kit provides an engaging and interactive way for students to explore renewable energy concepts and gain practical experience in STEM subjects.

INTRODUCTION AND THEORETICAL BASIS

The introduction to the Wind Turbine Model Kit provides students with an overview of the importance of wind energy as a renewable resource and its role in sustainable energy production. Students will learn about the increasing global demand for clean energy alternatives and the significance of harnessing wind power to mitigate climate change and reduce dependence on fossil fuels. Theoretical concepts related to wind energy conversion, including aerodynamics, rotor design, and electrical generation, are introduced to lay the groundwork for understanding how wind turbines operate. By delving into the theoretical basis of wind energy, students will develop a deeper appreciation for the scientific principles behind renewable energy technologies and their potential to address environmental challenges.

RATIONALE FOR CONDUCTING THE EXPERIMENT

The Wind Turbine Model Kit experiment lesson offers students a hands-on opportunity to explore the practical aspects of wind energy generation and its application in real-world scenarios. By engaging in this experiment, students can gain a deeper understanding of the fundamental principles underlying wind turbine technology and its role in sustainable energy production. Through practical experimentation, students will investigate various factors affecting wind turbine performance, such as blade design, wind speed, and turbine placement, and analyze their impact on electricity generation. This experiment also fosters critical thinking skills as students evaluate data, draw conclusions, and propose solutions to optimize wind turbine efficiency. Ultimately, by conducting this experiment, students will develop a comprehensive understanding of the challenges and opportunities associated with harnessing wind power and its implications for addressing global energy needs.

INVESTIGATIVE TASKS TO BE EXECUTED

1. **Blade Design Experiment**: Students will investigate the effect of different blade designs on wind turbine performance by constructing wind turbine models with varying blade shapes and sizes. They will measure the rotational speed and power output of each turbine design under controlled wind conditions to determine the most efficient blade configuration.

2. **Wind Speed Analysis**: Students will analyze the relationship between wind speed and electricity generation by recording the power output of the wind turbine model at different wind speeds. They will use an anemometer to measure wind speed and observe how changes in wind velocity impact turbine performance.

3. **Turbine Placement Study**: Students will explore the influence of turbine placement on energy production by positioning the wind turbine model in different locations relative to a simulated wind source. They will measure and compare the power output of the turbine when placed in various positions to identify the optimal placement for maximizing energy capture.

4. **Load Variation Experiment**: Students will investigate the effect of varying electrical loads on wind turbine performance by connecting different resistive loads to the turbine output. They will measure the voltage and current across the load resistor to calculate power output and analyze how changes in electrical load affect turbine operation.

Hypothesis: ***As we implement energy-saving strategies such as adjusting blade angles and optimizing turbine placement, we expect to observe a decrease in energy consumption and a corresponding reduction in CO_2 emissions.***

INVESTIGATIVE EXPERIMENT

EXPERIMENT 1: INVESTIGATING THE EFFECT OF DIFFERENT BLADE DESIGNS ON WIND TURBINE PERFORMANCE

Required materials:

- Wind turbine model kit with interchangeable blades
- Anemometer
- Data logger or recording device
- Stopwatch or timer
- Notebook / electronic table for recording observations

Procedure:

1. Set up the wind turbine model kit in a location with consistent wind flow.
2. Begin by attaching one type of blade to the turbine and ensuring it is securely fastened.
3. Use the anemometer to measure the wind speed at the turbine location.
4. Start the turbine and record the electricity generated over a set period, using the data logger.
5. Repeat steps 2-4 with each type of blade included in the kit.
6. Compare the electricity generation data for each blade design and analyze the differences in performance.
7. Record your observations and findings in the notebook / electronic table.

EXPERIMENT 2: ANALYZING THE RELATIONSHIP BETWEEN WIND SPEED AND ELECTRICITY GENERATION

Required materials:

- Wind turbine model kit
- Anemometer

- Data logger or recording device
- Stopwatch or timer
- Notebook / electronic table for recording observations

Procedure:

1. Set up the wind turbine model kit in an area with varying wind speeds.
2. Use the anemometer to measure the wind speed at regular intervals.
3. Start the turbine and record the electricity generated during each interval, using the data logger.
4. Plot a graph showing the relationship between wind speed and electricity generation.
5. Analyze the data to identify any patterns or correlations between wind speed and electricity output.
6. Record your observations and conclusions in the notebook / electronic table.

EXPERIMENT 3: EXPLORING THE INFLUENCE OF TURBINE PLACEMENT ON ENERGY PRODUCTION

Required materials:

- Wind turbine model kit
- Open area with varying wind conditions
- Anemometer
- Data logger or recording device
- Stopwatch or timer
- Notebook / electronic table for recording observations

Procedure:

1. Set up the wind turbine model kit in different locations, varying the distance from obstructions such as buildings or trees.

2. Use the anemometer to measure the wind speed at each location.
3. Start the turbine and record the electricity generated over a set period, using the data logger.
4. Compare the electricity generation data for each location and analyze the impact of turbine placement on energy production.
5. Record your observations and conclusions in the notebook / electronic table.

EXPERIMENT 4: INVESTIGATING THE EFFECT OF VARYING ELECTRICAL LOADS ON WIND TURBINE PERFORMANCE

Required materials:

- Wind turbine model kit
- Resistors or other electrical loads of varying resistance
- Voltmeter
- Data logger or recording device
- Stopwatch or timer
- Notebook / electronic table for recording observations

Procedure:

1. Set up the wind turbine model kit and connect it to a resistive load, such as a resistor.
2. Measure the voltage output of the turbine using the voltmeter.
3. Record the voltage output for each level of electrical load, adjusting the resistance as needed.
4. Start the turbine and record the electricity generated over a set period, using the data logger.
5. Analyze the relationship between electrical load and turbine performance, considering factors such as voltage output and power generation.
6. Record your observations and conclusions in the notebook / electronic table.

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EXERCISE 2: Utilizing Solar Energy

DESCRIPTION

When it comes to harnessing the power of the sun, the utilization of solar energy stands as a beacon of sustainable innovation. Solar energy, derived from the sun's radiant light and heat, offers a renewable and abundant source of power that holds the key to a cleaner and greener future. Through the use of photovoltaic cells or solar panels, sunlight is converted into electricity or utilized directly for heating and lighting purposes, making it an invaluable resource for a wide range of applications.

In this educational endeavor focusing on utilizing solar energy, students are invited to explore the fundamental principles of solar technology and its transformative potential. By delving into topics such as solar photovoltaics, solar thermal systems, and solar-powered devices, students gain insight into the mechanics of solar energy conversion and its practical applications in various sectors.

DIDACTIC-METHODICAL COMMENTARY

Through hands-on activities, experiments, and research projects, students are empowered to investigate the environmental benefits, economic viability, and technological advancements associated with solar energy utilization. From analyzing the efficiency of solar panels to designing solar-powered solutions for real-world challenges, students are encouraged to think critically, problem-solve creatively, and collaborate effectively in exploring the vast possibilities offered by solar energy.

As students engage in this educational journey, they not only expand their scientific knowledge and technical skills but also cultivate a deeper appreciation for sustainable living and environmental stewardship. By harnessing the power of solar energy, students become agents of change, driving forward the transition towards a more sustainable and resilient future for generations to come.

EXAMPLE RESOURCES FOR EXPERIMENTAL WORK IN STEM ENVIRONMENT ON THE TOPIC "UTILIZING SOLAR ENERGY":

Resource 1: *Solar Photovoltaic Cells – Harnessing Sunlight for Electricity Generation. Understanding the Principles and Functionality of Solar Panels.*

Resource 2: *Solar Water Heating Systems – Exploring Solar Thermal Technologies for Domestic and Industrial Applications. Determining the Efficiency of Solar Water Heaters.*

Resource 3: *Solar-Powered Devices – Designing and Constructing Solar Chargers, Lights, and Gadgets. Investigating the Practical Applications of Solar Energy in Everyday Life.*

SAMPLE INVESTIGATIVE QUESTIONS ON THE TOPIC INTENDED FOR PROJECT ACTIVITIES IN STEM ENVIRONMENT:

1. What are the key components of a solar photovoltaic cell, and how do they work together to convert sunlight into electricity?
2. How does the efficiency of solar panels vary based on factors such as angle of inclination, orientation, and shading?
3. What are the advantages and limitations of solar water heating systems compared to conventional water heating methods?
4. How can solar energy be utilized to power off-grid applications such as remote sensors, street lights, and communication devices?
5. What are the economic and environmental benefits of integrating solar energy systems into residential and commercial buildings?
6. How does the geographic location and climate conditions affect the feasibility and effectiveness of solar energy utilization?
7. What are the latest advancements in solar technology, and how do they contribute to improving the efficiency and affordability of solar energy systems?
8. How can solar energy be harnessed for agricultural purposes, such as irrigation, crop drying, and livestock management?
9. What are the challenges associated with solar energy storage and grid integration, and what innovative solutions are being developed to address these challenges?
10. How can individuals and communities advocate for policies and incentives to promote the widespread adoption of solar energy technologies?

Resource 1

SOLAR PHOTOVOLTAIC CELLS

BRIEF INFORMATION ABOUT THE LEARNING RESOURCE

Subjects	Chemistry, Physics, Biology, Information Technologies
Age	Students
Time for execution	2 hours

In the subtopic "Solar Photovoltaic Cells" students delve into the possible functions and structural composition of solar cells, utilizing working materials. The semiconductor sequences, for which these spatial coordinates are already known, are typically published in databases on the Internet. From there, students can download them to their own computers and visualize them as 3D models. Using the example of solar photovoltaic cells, it demonstrates how 3D models can be utilized to understand the structure and functioning of these cells. Additionally, this context delves into the exploration of various semiconductor materials used in solar panels, such as silicon-based solar cells and alternative materials.

INTRODUCTION AND THEORETICAL BASIS

Solar photovoltaic cells play various essential functions in capturing and converting sunlight into electricity. Therefore, they are of particular importance to the subject of chemistry and are also suitable for the subject of physics as photovoltaic devices. Students are required to conduct research experiments to verify the composition and some of the properties of solar cells. The biosynthesis of solar cells can be examined in-depth.

RATIONALE FOR CONDUCTING THE EXPERIMENT

Students use this material to develop basic knowledge about solar cells. To do this, they first compile the possible functions of solar cells in a clear manner. Then, they deal with the structure of the individual photovoltaic cells, their connections, and the spatial arrangement of the solar cell residues. Photovoltaic cells are the building blocks of solar panels, but they also have many other functions in the solar energy system. Some photovoltaic cells are essential, meaning they must be obtained from the environment, while others can be produced by the body itself. If desired, the topic can be deepened in the direction of solar cell biosynthesis or solar cell modifications or can be introduced to the solar cell database.

INVESTIGATIVE TASKS TO BE EXECUTED

1. Investigate the effect of varying light intensity on the electricity output of solar photovoltaic cells by using a light source (such as a lamp) placed at different distances from the solar cell. Measure and record the voltage and current produced by the solar cell at each light intensity level.

2. Explore the impact of temperature on the efficiency of solar photovoltaic cells by heating or cooling the solar cell using a heat source or ice pack, respectively. Measure and compare the electricity output of the solar cell at different temperature levels.

3. Analyze the influence of different materials on the performance of solar photovoltaic cells by constructing solar cells using various semiconductor materials (such as silicon, gallium arsenide, or cadmium telluride). Compare the electricity output and efficiency of each solar cell material.

4. Investigate the angle dependence of solar photovoltaic cells by tilting the solar panel at different angles relative to the incoming sunlight. Measure and compare the electricity output of the solar panel at various tilt angles to determine the optimal orientation for maximum energy generation.

Hypothesis: ***The composition and properties of solar photovoltaic cells can be determined experimentally by investigating the impact of various parameters such as light intensity, temperature, and material characteristics used in constructing the cell.***

INVESTIGATIVE EXPERIMENT

EXPERIMENT 1: INVESTIGATING THE EFFECT OF VARYING LIGHT INTENSITY ON SOLAR PHOTOVOLTAIC CELLS

Required materials:

- Solar photovoltaic cell
- Light source (lamp)
- Light intensity meter or lux meter
- Multimeter

Procedure:

1. Set up the solar photovoltaic cell in a well-lit area with access to electrical outlets.
2. Place the light source (lamp) at a fixed distance from the solar cell.
3. Measure and record the initial voltage and current output of the solar cell using a multimeter.
4. Turn on the light source and adjust its intensity (brightness) to a predetermined level using a light intensity meter or lux meter.
5. Allow the solar cell to be exposed to the light source for a set period of time (e.g., 5 minutes).
6. After the exposure period, measure and record the voltage and current output of the solar cell using the multimeter.
7. Repeat steps 4-6 for different light intensity levels by adjusting the brightness of the light source.
8. Analyze the data to observe the relationship between light intensity and electricity output of the solar cell.

EXPERIMENT 2: EXPLORING THE IMPACT OF TEMPERATURE ON SOLAR PHOTOVOLTAIC CELLS

Required materials:

- Solar photovoltaic cell
- Heat source (e.g., lamp or hair dryer) or ice pack
- Temperature sensor or thermometer
- Multimeter

Procedure:

1. Set up the solar photovoltaic cell in a controlled environment with access to electrical outlets.
2. Measure and record the initial voltage and current output of the solar cell using a multimeter.

3. If investigating the effect of heat, turn on the heat source (lamp or hair dryer) and position it at a fixed distance from the solar cell. If investigating the effect of cold, apply an ice pack to the solar cell to lower its temperature.

4. Allow the solar cell to be exposed to the heat source or ice pack for a set period of time (e.g., 5 minutes).

5. During the exposure period, continuously monitor the temperature of the solar cell using a temperature sensor or thermometer.

6. After the exposure period, measure and record the voltage and current output of the solar cell using the multimeter.

7. Repeat steps 3-6 for different temperature levels.

8. Analyze the data to observe the relationship between temperature and electricity output of the solar cell.

EXPERIMENT 3: ANALYZING THE INFLUENCE OF DIFFERENT MATERIALS ON SOLAR PHOTOVOLTAIC CELLS

Required materials:

- Solar photovoltaic cell
- Various semiconductor materials (e.g., silicon, gallium arsenide, cadmium telluride)
- Multimeter
- Light source (lamp)

Procedure:

1. Construct solar cells using different semiconductor materials (e.g., silicon, gallium arsenide, cadmium telluride) according to established protocols or manufacturer instructions.

2. Ensure all solar cells are of the same size and configuration for consistency.

3. Set up each solar cell in a controlled environment with access to electrical outlets.

4. Measure and record the initial voltage and current output of each solar cell using a multimeter.

5. Expose all solar cells to the same light intensity level using a lamp or other light source.

6. Allow the solar cells to be exposed to the light source for a set period of time (e.g., 5 minutes).

7. After the exposure period, measure and record the voltage and current output of each solar cell using the multimeter.

8. Compare the electricity output and efficiency of each solar cell material.

9. Analyze the data to observe the impact of different semiconductor materials on the performance of solar photovoltaic cells.

EXPERIMENT 4: INVESTIGATING THE ANGLE DEPENDENCE OF SOLAR PHOTOVOLTAIC CELLS

Required materials:

- Solar panel
- Adjustable mounting stand or support
- Light source (e.g., lamp)
- Multimeter

Procedure:

1. Set up the solar panel on an adjustable mounting stand or support in a well-lit area with access to electrical outlets.

2. Adjust the angle of the solar panel relative to the incoming sunlight to various tilt angles (e.g., 0°, 30°, 60°).

3. Measure and record the initial voltage and current output of the solar panel using a multimeter.

4. Turn on the light source (lamp) and position it at a fixed distance from the solar panel.

5. Allow the solar panel to be exposed to the light source for a set period of time (e.g., 5 minutes).

6. During the exposure period, maintain the solar panel at the predetermined tilt angle.

7. After the exposure period, measure and record the voltage and current output of the solar panel using the multimeter.

8. Repeat steps 2-7 for different tilt angles.

9. Analyze the data to determine the optimal tilt angle for maximum energy generation.

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EXERCISE 3: The Impact of CO_2 Footprint and Implementing Reduction Strategies

DESCRIPTION

In this lesson, students will embark on a journey to deepen their understanding of the impact of carbon dioxide (CO_2) emissions on the environment and explore practical measures to reduce their carbon footprint. Through engaging discussions and interactive activities, students will uncover the interconnectedness between human activities and climate change, with a specific focus on the role of CO_2 emissions in driving global warming and environmental degradation. They will learn about the various sources of carbon emissions, including transportation, energy consumption, and industrial processes, gaining insights into how individual actions contribute to the collective carbon footprint.

Furthermore, students will delve into the significance of measuring carbon footprint as a vital step towards environmental accountability and sustainability. They will explore different methods and tools used to calculate carbon emissions, ranging from online calculators to more comprehensive life cycle assessments. By gaining practical experience in measuring their own carbon footprint, students will develop a deeper awareness of their environmental impact and the importance of making informed choices to reduce emissions. Through this exploration, students will be empowered to take meaningful action towards mitigating climate change and fostering a more sustainable future.

DIDACTIC-METHODICAL COMMENTARY

Throughout this lesson, a student-centered approach will be employed to foster active engagement and critical thinking among students. Collaborative learning activities, such as group discussions and problem-solving tasks, will encourage students to exchange ideas, share perspectives, and collectively explore solutions to reduce carbon emissions. Additionally, hands-on experiments and interactive demonstrations will provide students with tangible experiences to deepen their understanding of carbon footprint measurement and reduction strategies. Furthermore, the integration of multimedia resources, including videos, infographics, and interactive simulations, will cater to diverse learning styles and enhance comprehension of complex environmental concepts. By incorporating inquiry-based learning methods and real-world applications, this lesson aims to empower students to become agents of change in promoting environmental sustainability within their communities.

EXAMPLE RESOURCES FOR EXPERIMENTAL WORK IN STEM ENVIRONMENT ON THE TOPIC "THE IMPACT OF CO_2 FOOTPRINT AND IMPLEMENTING REDUCTION STRATEGIES":

Resource 1: *Energy Efficiency and CO_2 Emissions Monitoring with STEM Tools: Provide students with STEM tools such as energy meters or environmental sensors equipped with CO_2 sensors that can be connected to smartphones or tablets. Students can use these tools to simultaneously measure energy consumption and CO_2 emissions in different areas of their school or home, such as classrooms, laboratories, or common areas. By collecting and analyzing energy data alongside CO_2 emissions, students gain a comprehensive understanding of their environmental impact and can identify opportunities for reducing both energy usage and carbon emissions.*

Resource 2: *Carbon Footprint Tracking App: Introduce students to smartphone apps designed for tracking carbon footprint. Apps such as "Capture" or "Footprint" allow users to input their daily activities, including transportation, energy consumption, and food choices, to calculate their carbon emissions. Students can use these apps to monitor their carbon footprint over time, set reduction goals, and explore ways to minimize their environmental impact.*

Resource 3: *Sustainable Transportation Challenge: Engage students in a sustainable transportation challenge using smartphone apps and GPS tracking tools. Students can use apps like "Strava" or "Google Maps" to track their daily commuting routes and modes of transportation, such as walking, biking, carpooling, or using public transit. Through data collection and analysis, students can compare the carbon emissions associated with different transportation options and explore ways to reduce their carbon footprint by promoting sustainable commuting practices within their school or community.*

SAMPLE INVESTIGATIVE QUESTIONS ON THE TOPIC INTENDED FOR PROJECT ACTIVITIES IN STEM ENVIRONMENT:

1. What are the primary sources of CO_2 emissions in our university or home, and how do they correlate with energy usage patterns?
2. How do changes in temperature affect energy consumption and CO_2 emissions in indoor environments, and what strategies can be implemented to optimize heating and cooling systems?

3. What is the impact of lighting choices (e.g., incandescent, fluorescent, LED) on energy usage and CO_2 emissions, and how can lighting efficiency be improved?

4. How do energy-saving behaviors, such as turning off lights and unplugging electronics, influence overall energy consumption and CO_2 emissions over time?

5. What are the differences in energy consumption and CO_2 emissions between weekdays and weekends, and how can energy-saving practices be tailored to accommodate these variations?

6. How do transportation choices impact overall CO_2 emissions, and what alternatives exist to promote sustainable commuting practices within our school or community?

7. How can renewable energy sources, such as solar panels or wind turbines, be integrated into our school or home to reduce reliance on fossil fuels and mitigate CO_2 emissions?

8. What role can data visualization and analysis play in raising awareness about energy usage and CO_2 emissions and motivating behavior change towards sustainability?

9. How does energy consumption vary across different areas of our university or home, and what factors contribute to these variations?

10. How can we collaborate with local stakeholders, such as energy providers or environmental organizations, to implement effective energy efficiency measures and reduce CO_2 emissions in our community?

Resource 1

ENERGY EFFICIENCY AND CO_2 EMISSIONS MONITORING WITH STEM TOOLS

BRIEF INFORMATION ABOUT THE LEARNING RESOURCE

Subjects	Chemistry, Physics, Biology, Information Technologies
Age	Students
Time for execution	2 hours

The subtopic "Energy Efficiency and CO_2 Emissions Monitoring With Stem Tools," provides students with hands-on experience in monitoring and analyzing energy consumption and CO_2 emissions using STEM tools. Through this project, students will gain practical skills in data collection, analysis, and interpretation while exploring the relationship between energy usage and environmental impact. By engaging in real-world applications of STEM principles, students will develop a deeper understanding of energy efficiency and sustainability and be empowered to make informed decisions to reduce their carbon footprint.

INTRODUCTION AND THEORETICAL BASIS

In today's world, understanding and addressing energy efficiency and CO_2 emissions are paramount for sustainability. Through this project, students will delve into the theoretical basis of energy monitoring and CO_2 emissions, using STEM tools to analyze data and propose solutions for a greener future.

Energy efficiency and CO_2 emissions monitoring relies on principles of physics, environmental science, and data analysis. By exploring concepts such as energy conservation, greenhouse gas emissions, and sustainability, students will develop a holistic understanding of the factors influencing energy consumption and environmental impact.

RATIONALE FOR CONDUCTING THE EXPERIMENT

The rationale for conducting this experiment lies in the urgent need to address climate change and promote sustainable practices. By monitoring energy efficiency and CO_2 emissions with STEM tools, students gain practical insights into environmental impact and are empowered to advocate for positive change within their communities. Additionally, this experiment fosters critical thinking and problem-solving skills, preparing students to tackle complex environmental challenges in the future.

INVESTIGATIVE TASKS TO BE EXECUTED

1. Measure and analyze energy consumption: Use STEM tools to collect data on energy usage in different areas of the university campus or home, including electricity, heating, and transportation. Analyze the data to identify trends and patterns in energy consumption.

2. Monitor CO_2 emissions: Utilize STEM tools to measure and monitor CO_2 emissions associated with energy usage and transportation. Compare CO_2 emission levels between different activities and identify sources of high emissions.

3. Investigate energy-saving strategies: Research and implement energy-saving strategies such as improving insulation, using energy-efficient appliances, and promoting sustainable transportation options. Measure the impact of these strategies on energy consumption and CO_2 emissions.

4. Analyze data and propose solutions: Analyze the collected data to identify areas for improvement and propose solutions to reduce energy consumption and CO_2 emissions. Develop action plans and implement changes to promote energy efficiency and sustainability.

Hypothesis: ***Implementing energy-saving strategies and promoting sustainable practices, as identified through monitoring energy consumption and CO_2 emissions with STEM tools, will lead to a measurable reduction in both energy consumption and CO_2 emissions.***

INVESTIGATIVE EXPERIMENT

EXPERIMENT 1: MEASURING AND ANALYZING ENERGY CONSUMPTION

Required materials:

- STEM tools for energy monitoring (e.g., energy meters, smart plugs)
- Paper and pen for recording data / Computer with Microsoft Excel program
- Access to electricity usage data (e.g., utility bills, online monitoring platforms)

Procedure:

1. Identify the areas or devices to be monitored for energy consumption (e.g., classrooms, computers, lighting).
2. Install energy meters or smart plugs on selected devices or in designated areas to measure electricity usage.
3. Record baseline energy consumption data over a set period (e.g., one week) using STEM tools.
4. Analyze the collected data to identify trends and patterns in energy consumption, such as peak usage times or energy-intensive activities.
5. Compare energy consumption between different areas or devices to prioritize areas for energy-saving interventions.
6. Use the data to develop strategies for reducing energy consumption, such as turning off lights when not in use or optimizing heating and cooling systems.

EXPERIMENT 2: MONITORING CO_2 EMISSIONS

Required materials:

- CO_2 monitoring devices or sensors
- Paper and pen for recording data / Computer with Microsoft Excel program
- Access to transportation data (e.g., mileage records, fuel consumption)

Procedure:

1. Determine the sources of CO_2 emissions to be monitored, such as transportation or energy usage.
2. Install CO_2 monitoring devices or sensors in relevant areas (e.g., vehicles, classrooms) to measure CO_2 emissions.
3. Record baseline CO_2 emission data over a set period (e.g., one week) using STEM tools.
4. Analyze the collected data to identify sources of high CO_2 emissions and potential areas for improvement.
5. Compare CO_2 emissions between different activities or modes of transportation to prioritize areas for emission reduction.
6. Use the data to develop strategies for reducing CO_2 emissions, such as promoting walking or biking instead of driving or using energy-efficient transportation options.

EXPERIMENT 3: INVESTIGATING ENERGY-SAVING STRATEGIES

Required materials:

- Materials for implementing energy-saving strategies (e.g., insulation, energy-efficient appliances)
- Paper and pen for recording data / Computer with Microsoft Excel program
- Access to energy consumption data (collected in Experiment 1)

Procedure:

1. Research energy-saving strategies that are feasible for the environment being studied (e.g., school, home).
2. Implement selected energy-saving strategies in designated areas or with specific devices, such as installing insulation or upgrading to energy-efficient appliances.
3. Record data on energy consumption before and after implementing energy-saving strategies.
4. Analyze the collected data to assess the effectiveness of the implemented strategies in reducing energy consumption.

5. Identify any challenges or barriers to implementing energy-saving strategies and brainstorm potential solutions.

6. Use the findings to refine and optimize energy-saving strategies for maximum effectiveness.

EXPERIMENT 4: ANALYZE DATA AND PROPOSE SOLUTIONS

Required materials:

- Data collected from Experiments 1-3
- Paper and pen for recording observations and proposed solutions / Computer with Microsoft Excel program

Procedure:

1. Compile and organize data collected from Experiments 1-3, including energy consumption, CO_2 emissions, and the effectiveness of energy-saving strategies.

2. Analyze the data to identify trends, patterns, and correlations between energy consumption, CO_2 emissions, and implemented strategies.

3. Evaluate the success of implemented strategies in achieving energy efficiency and reducing CO_2 emissions.

4. Identify areas for improvement and potential solutions based on the analysis of the collected data.

5. Develop action plans and propose solutions for further reducing energy consumption and CO_2 emissions, considering factors such as feasibility, cost-effectiveness, and environmental impact.

6. Present findings and proposed solutions to relevant stakeholders (e.g., school administrators, community members) and collaborate on implementing changes for a more sustainable future.

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TEACHING MATERIALS AND EXAMPLES OF GOOD PRACTICES

COURSE:

SUSTAINABLE TECHNOLOGIES IN SCIENCE EDUCATION

EXERCISE 1: Water Electrolyzer

DESCRIPTION

The electrochemical water cycle encompasses a range of technologies and processes that leverage electrochemical principles to manipulate water for various purposes, including energy generation (fuel cells) and storage (electrolyzer). These technologies hold significant promise in addressing challenges related to sustainable energy production and environmental pollution.

Electrolysis is a fundamental electrochemical process and can be considered as one step in the electrochemical water cycle. A water electrolyzer is a device that utilizes an electrochemical process called electrolysis to split water (H_2O) into its constituent elements, hydrogen (H_2) and oxygen (O_2), using an electric current. This process typically takes place in an electrolytic cell containing electrodes submerged in an electrolyte solution, which is usually a solution of acid, base, or salt in water to enhance its conductivity.

DIDACTIC-METHODICAL COMMENTARY

This teaching unit is designed as step-by-step instruction. Students will find out more about electrolysis, a key process in sustainable energy production through experimental work and by using textbooks and other available sources.

EXAMPLE RESOURCES FOR EXPERIMENTAL WORK IN STEM ENVIRONMENT ON THE TOPIC "Water Electrolyzer"[1]

Resource 1: *Simple water electrolyzer. To build a low-cost water electrolyzer using common materials and to analyze the influence of practical experiments on hydrogen production.*

SAMPLE INVESTIGATIVE QUESTIONS ON THE TOPIC INTENDED FOR PROJECT ACTIVITIES IN STEM ENVIRONMENT:

Specific engineering questions:

1. How does varying the voltage affect the rate of hydrogen and oxygen production during electrolysis?
2. What is the optimal concentration of electrolyte solution for maximizing the efficiency of electrolysis?
3. How do different electrode materials impact the efficiency and longevity of the electrolysis process?
4. How can the energy efficiency of water electrolysis be improved to reduce overall energy consumption?
5. What are the environmental impacts associated with different electrolysis methods, and how can they be minimized?
6. Are there novel catalysts or materials that can enhance the performance and sustainability of water electrolysis?

Hydrogen storage and utilization:

1. What are the most effective methods for storing and transporting hydrogen produced from water electrolysis?
2. How can hydrogen be efficiently utilized as a clean energy carrier in fuel cells or other applications?
3. What are the economic and technical barriers to widespread adoption of hydrogen fuel derived from water electrolysis?

General sustainability questions:

1. How can surplus electricity from renewable energy sources be effectively utilized for electrolysis to produce hydrogen for energy storage?
2. What are the technical and economic challenges of integrating hydrogen produced from water electrolysis into existing renewable energy systems?
3. Can electrolyzers be optimized for on-site hydrogen production in remote or off-grid locations powered by renewable energy?
4. How can public perception and understanding of water electrolysis be improved to foster support for research and development in this area?

Resource 1

SIMPLE WATER ELECTROLYZER

BRIEF INFORMATION ABOUT THE LEARNING RESOURCE

Subjects	Chemistry, Physics, …
Age	Students
Time for execution	3 hours

This learning resource aims to provide a thorough understanding of water electrolysis, a key process in sustainable energy production and storage. It covers the principles, applications, and significance of electrolysis in various fields, including renewable energy, environmental science, and engineering.

INTRODUCTION AND THEORETICAL BASIS

This learning resource serves as a valuable reference for students, educators, researchers, and anyone interested in gaining a basic understanding of water electrolysis and its role in advancing sustainable energy technologies. With comprehensive coverage of fundamental concepts, practical applications, and educational resources, it aims to foster knowledge, innovation, and collaboration in the field of electrolysis and renewable energy. Key Topics that should be covered are:

Introduction to Electrolysis:

- Definition and basic principles of electrolysis
- Historical background and development of electrolysis technology

Electrochemical Reactions:

- Explanation of the chemical reactions involved in water electrolysis
- Equations representing the electrolysis process and the formation of hydrogen and oxygen gases

Components of Electrolysis Systems:

- Description of electrolysis cells and their components (electrodes, electrolyte, power supply)
- Types of electrolysis cells (e.g., alkaline electrolyzers, PEM electrolyzers)

Factors Affecting Electrolysis Efficiency:

- Influence of voltage, current density, temperature, and electrolyte concentration on electrolysis performance
- Optimization strategies for improving electrolysis efficiency and reducing energy consumption

Applications of Water Electrolysis:

- Production of hydrogen for fuel cells, transportation, and industrial processes
- Energy storage and grid balancing using hydrogen generated from electrolysis
- Water treatment, desalination, and environmental remediation applications

Challenges and Future Directions:

- Technical and economic challenges associated with water electrolysis
- Research advancements and emerging technologies in electrolysis for sustainable energy

Educational Resources and Activities:

- Hands-on experiments, simulations, and educational materials for teaching and learning about water electrolysis in STEM disciplines
- Resources for educators, students, and researchers interested in exploring electrolysis concepts and applications

RATIONALE FOR CONDUCTING THE EXPERIMENT

The rationale for conducting a simple water electrolyzer experiment lies in its potential to offer valuable insights into fundamental principles of electrochemistry, sustainable energy production, and STEM education. In particular, by conducting a water electrolyzer experiment, students or teachers can gain a deeper understanding of the electrolysis process, which involves the conversion of electrical energy into chemical energy. This hands-on activity allows participants to observe firsthand how electrical current can induce chemical reactions, splitting water molecules into hydrogen and oxygen gases. Further, by constructing and operating a simple electrolyzer, participants can explore the potential of hydrogen as a sustainable fuel source for various applications, including fuel cells, transportation, and energy storage. Finally, simple water electrolyzer experiments can inspire curiosity and creativity, encouraging participants to explore alternative materials, designs, and methods for improving electrolysis efficiency and performance. Through iterative experimentation and problem-solving, students and teachers can develop innovative solutions to real-world challenges in energy production and storage.

INVESTIGATIVE TASKS TO BE EXECUTED

1. **Determination of anode and cathode**: By quantifying the volume of gases evolved, students can discern the identity of each electrode, distinguishing between the cathode and the anode. This understanding allows them to correlate each electrode with its respective role in the subsequent electrochemical reactions occurring within the electrolyzer.
2. **Use of different electrode materials:** Students will investigate the impact of various electrode materials on the efficiency of the electrolyzer. The surface of the electrode serves as an electrocatalyst, influencing the rate and selectivity of the electrochemical reactions involved in water electrolysis. By introducing different electrode materials, students can significantly alter the electrolyzer's activity, stability, and the selectivity of the electrocatalyst.
3. **Voltage Variation Experiment**: Students will investigate the effect of varying battery voltage on electrolyzer performance by connecting different batteries to the electrolyzer. They will measure the time to achieve the production of the same volume of hydrogen.
4. **pH measurements of electrolyte**: Students will conduct pH measurements of the electrolyte both before and after the electrolysis experiment to gain insights into the underlying electrochemical reactions.

Hypothesis: ***By implementing energy-saving strategies, such as adjusting voltage and current densities, as well as modifying electrode materials, we anticipate observing alterations in hydrogen production rates.***

INVESTIGATIVE EXPERIMENT

EXPERIMENT 1: Buiding and testing simple water electrolyzer[2,3]

Required materials:

- Water cup
- 2 glass test tubes
- 2 metal push pins or 2 graphite pencils
- Alligator clips electrical test leads set of 2
- 9 V batteries
- Water
- Baking soda or sodium chloride
- Stopwatch
- Notebook / electronic table for recording observations

Procedure:

1. Stick push pins through the bottom of a cup, ensuring their distance matches that between the terminals of a 9-volt battery, with the pointed ends inside the cup. Sharpen the pencil on both ends.
2. Fill the cup with water and dissolve a spoonful of salt or baking soda to enhance electrical conduction. Use warm water and aim for a ratio of approximately 1 part salt or baking soda to 10 parts water. If there are no bubbles when starting the experiment, add more salt.
3. Connect the battery to the pins or alligator clips. Place the cup on top of the battery so that one pin rests on the positive terminal and the other on the negative terminal. If using alligator clips, attach one to the positive terminal and the other to the negative terminal and connect the other side to the pencils and dip them in the electrolyte. Observe the bubbles forming on the pins or pencils as they separate hydrogen and oxygen. Ensure that the pins or pencils do not touch, as this would disrupt the circuit.
4. Invert test tubes over the pins or pencils, submerging them in the water. Allow the tubes to fill with gas, displacing the water. The gases collected will be hydrogen and oxygen, which are colorless. You've also produced a tiny amount of chlorine gas if NaCl was used during this experiment. Don't worry though, you haven't created nearly enough to be dangerous. Differentiate between them by observing which tube fills up faster.
5. Utilize a stopwatch to precisely measure the time it takes for the test tube with the larger volume to reach the predetermined level.

EXPERIMENT 2: Measuring the pH of the electrolyte before and after electrolysis

Required materials:

- universal pH indicator
- vinegar
- baking soda

Procedure:

1. If the pH is alkaline ($pH > 7$), dilute the electrolyte with vinegar and thoroughly wash everything with soap and water. Failing to add vinegar to the electrolyte could potentially lead to damage to your sink or pipes.
2. If the pH is acidic ($pH < 7$), dilute the electrolyte with a baking soda solution and ensure to wash all surfaces thoroughly with soap and water. Neglecting to add the baking soda solution to the electrolyte might result in damage to your sink or pipes.

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EXERCISE 2: Proton-exchange membrane fuel cell

DESCRIPTION

Energy cannot be created or destroyed; it simply changes form. When energy shifts into a form that isn't effectively utilized, we label it as wasted. Thus, the general goal is to minimize energy wastage during energy conversion by maximizing the conversion into useful forms.

Gasoline-powered vehicles face this dilemma daily. Internal combustion engines, relying on gasoline, generally peak at around 40% efficiency. Consequently, a significant portion of energy conversion within these engines fails to serve their primary purpose—propulsion. Instead, the potential energy stored in gasoline dissipates as sound, vibration, and heat.

In contrast, fuel cells consistently achieve efficiencies of around 60% in stacks, with upper limits reaching 85%. Due to their lack of moving parts, fuel cells experience minimal energy loss due to heat and friction.

A Proton Exchange Membrane (PEM) fuel cell is a type of electrochemical cell that operates at relatively low temperatures, typically around 80°C, making it suitable for various applications, including transportation and stationary power generation. The heart of a PEM fuel cell is the proton exchange membrane, which selectively allows protons to pass through while blocking electrons. This membrane separates the anode and cathode compartments, where hydrogen and oxygen reactions occur respectively. As hydrogen molecules split into protons and electrons at the anode, the protons move through the membrane to the cathode, while the electrons travel through an external circuit, generating electrical power. At the cathode, oxygen combines with the protons and electrons to form water and heat, the only byproducts of the reaction. The efficiency, scalability, and environmentally friendly nature of PEM fuel cells make them a promising technology for a sustainable energy future

DIDACTIC-METHODICAL COMMENTARY

This teaching unit is designed as step-by-step instruction. Students will find out more about principles, applications, and importance of Proton Exchange Membrane (PEM) fuel cells, through experimental work and by using textbooks and other available sources.

EXAMPLE RESOURCES FOR EXPERIMENTAL WORK IN STEM ENVIRONMENT ON THE TOPIC "Simple hydrogen fuel cell"

Resource 1: *Simple hydrogen fuel cell. To assemble a simple hydrogen fuel cell using a commercial chemical and materials and gain insight into the fundamental principles governing real-scale fuel cell vehicles currently available on the market.*

SAMPLE INVESTIGATIVE QUESTIONS ON THE TOPIC INTENDED FOR PROJECT ACTIVITIES IN STEM ENVIRONMENT:

1. How does the efficiency of PEM fuel cells compare to other types of fuel cells, such as alkaline or solid oxide fuel cells?
2. What are the primary factors influencing the durability and longevity of PEM fuel cell stacks under various operating conditions?
3. How can the cost-effectiveness of PEM fuel cell manufacturing processes be improved to facilitate widespread adoption in transportation and stationary applications?
4. What advancements in catalyst materials and designs are being explored to enhance the performance and reduce the cost of PEM fuel cells?
5. How does the operating temperature affect the overall efficiency and performance of PEM fuel cells, and what strategies can be employed to optimize temperature management?
6. What are the challenges associated with hydrogen storage and distribution for PEM fuel cell-powered vehicles, and what innovative solutions are being developed to address these challenges?
7. How can PEM fuel cell technology be integrated with renewable energy sources like solar or wind power to create more sustainable energy systems?
8. What are the environmental impacts of PEM fuel cell production, operation, and disposal, and how do they compare to traditional combustion-based technologies?
9. What are the potential applications for PEM fuel cells in off-grid or remote locations, and what are the technical and logistical challenges associated with deploying them in such environments?
10. How can PEM fuel cell systems be optimized for specific applications, such as backup power for telecommunications infrastructure or portable electronic devices, in terms of size, weight, and reliability?

Resource 1

Simple hydrogen fuel cell

BRIEF INFORMATION ABOUT THE LEARNING RESOURCE

Subjects	Chemistry, Physics, …
Age	Students
Time for execution	5 hours

This learning resource is designed to help gain a solid understanding of Proton Exchange Membrane (PEM) fuel cells, which are essential for sustainable energy production and storage. It explores the principles, applications, and importance of PEM fuel cells in various fields such as renewable energy, environmental science, and engineering, making it accessible and relevant across diverse domains.

INTRODUCTION AND THEORETICAL BASIS

This learning resource serves as a valuable reference for students, educators, researchers, and anyone interested in gaining a basic understanding of PEM fuel cells and its role in advancing sustainable energy technologies. With comprehensive coverage of fundamental concepts, practical applications, and educational resources, it aims to foster knowledge, innovation, and collaboration in the field of electrocatalysis and renewable energy. Key Topics that should be covered:

Electrochemical Fundamentals: Understanding the basic principles of electrochemistry, including redox reactions, electron transfer mechanisms, and ion transport processes, is crucial for grasping the operation of PEM fuel cells.

PEM Fuel Cell Components: Exploring the various components of a PEM fuel cell, such as the anode, cathode, proton exchange membrane, catalyst layers, bipolar plates, and gas diffusion layers, and their roles in facilitating electrochemical reactions and ion transport.

Operating Principles: Understanding of the operating principles of PEM fuel cells, including the hydrogen oxidation reaction at the anode, oxygen reduction reaction at the cathode, proton conduction through the membrane, and electron flow through the external circuit.

Catalysts and Materials: Examining the types of catalysts used in PEM fuel cells, such as platinum-based catalysts, and exploring alternative materials and catalyst designs aimed at reducing costs and improving performance.

Water Management: Understanding the importance of water management in PEM fuel cells, including the control of water distribution, removal of excess water, and prevention of membrane dehydration or flooding, to ensure optimal cell performance and durability.

Thermal Management: Addressing thermal management challenges in PEM fuel cells, such as maintaining optimal operating temperatures, heat dissipation, and managing thermal gradients within the cell stack.

System Integration: Considering the integration of PEM fuel cells into various applications, including transportation (e.g., fuel cell vehicles), stationary power generation (e.g., backup power systems), and portable electronics, and discussing system design considerations and challenges.

Performance and Efficiency: Evaluating the performance metrics and efficiency of PEM fuel cells, including power density, voltage efficiency, current density, and overall system efficiency, and discussing strategies for improving performance and efficiency.

Durability and Reliability: Investigating factors affecting the durability and reliability of PEM fuel cells, such as catalyst degradation, membrane degradation, and system degradation over time, and exploring strategies for enhancing cell durability and extending lifespan.

Market Trends and Future Outlook: Analyzing current market trends, technological advancements, and future prospects for PEM fuel cells, including potential applications, commercialization efforts, policy incentives, and research directions aimed at advancing the technology and expanding its adoption

RATIONALE FOR CONDUCTING THE EXPERIMENT

The rationale for conducting experiments with a PEM fuel cell is multi-faceted and encompasses several key objectives. Building a simple PEM fuel cell provides hands-on learning experiences that allow students to explore the principles of electrochemistry, energy conversion, and renewable energy technologies. By conducting experiments with the fuel cell, students can better understand how PEM fuel cells function and the underlying scientific concepts involved. Further, experimentation with a fuel cell science kit reinforces theoretical concepts taught in STEM programs. Through practical demonstrations and observations, students can solidify their understanding of topics like redox reactions, electrolysis, electron transfer, and proton conductivity. Working with a PEM fuel cell science kit cultivates various skills, including critical thinking, problem-solving, experimental design, data analysis, and teamwork. Participants learn to troubleshoot issues, interpret experimental results, and collaborate effectively to achieve common goals, enhancing their scientific literacy and proficiency.

INVESTIGATIVE TASKS TO BE EXECUTED

1. **Efficiency Analysis:** Measure the efficiency of the PEM fuel cell system by calculating the energy input (from hydrogen) and the electrical output (generated by the fuel cell) to assess its overall efficiency in converting chemical energy to electrical energy.
2. **Performance Testing:** Conduct performance tests under different operating conditions (e.g., varying hydrogen flow rates, temperature, and humidity levels) to evaluate how these factors affect the output voltage, current, and power of the fuel cell system.
3. **Water Management Assessment:** Investigate the effectiveness of water management within the PEM fuel cell system by monitoring the accumulation and removal of water during operation, ensuring proper hydration of the proton exchange membrane and preventing flooding or drying out.
4. **Durability Evaluation:** Assess the durability and long-term stability of the PEM fuel cell system by subjecting it to continuous operation or cyclic stress testing to simulate real-world usage conditions and identify potential degradation mechanisms.
5. **System Optimization:** Experiment with different system configurations, including varying the design of the fuel cell stack, the composition of catalyst materials, and the layout of balance of plant components, to optimize the performance, efficiency, and durability of the PEM fuel cell car.
6. **Environmental Impact Analysis:** Investigate the environmental impact of operating the PEM fuel cell car by measuring emissions (or lack thereof) and comparing them to conventional

combustion-based vehicles to assess the potential environmental benefits of fuel cell technology.

7. **Comparative Studies:** Compare the performance, efficiency, and cost-effectiveness of the PEM fuel cell car with other types of alternative energy vehicles (e.g., battery electric vehicles) to understand its strengths, limitations, and competitiveness in the transportation sector.

Hypothesis: By modifying *electrode materials, we anticipate observing alterations in output voltage.*

INVESTIGATIVE EXPERIMENT

EXPERIMENT 1: "Building simple hydrogen fuel cell"

Required materials:

- 20 cm platinum-coated nickel wire, or pure platinum wire.
- small piece of wood or plastic.
- 9 V battery clip.
- 9 V battery
- Some transparent scotch tape.
- 1 dL Glass
- 1 dL of water.
- Multimeter or red diode

Procedure:[1]

1. Begin by carefully cutting the platinum-coated wire into two equal segments. Then, delicately coil each segment into small springs, shaping them to serve as electrodes within the fuel cell.
2. Next, halve the leads of the battery clip, removing any insulation from the cut ends. Twist the exposed wires securely onto the ends of the platinum-coated electrodes. These connections will allow the battery clip to attach to the electrodes, while two additional wires will be affixed to later connect to the voltmeter.
3. Securely tape the electrodes onto a small piece of wood or plastic. This assembly is then affixed to the glass of water, ensuring that the electrodes hang submerged for nearly their entire length. Be cautious to keep the twisted wire connections above the waterline, leaving only the platinum-coated electrodes immersed.
4. Connect the red wire to the positive terminal and the black wire to the negative terminal of the multimeter or diode. Confirm that the voltmeter registers a reading of 0 volts.

5. To activate the fuel cell, initiate the evolution of hydrogen bubbles on one electrode and oxygen bubbles on the other. Achieve this by connecting the battery clip to a 9 V battery. The voltmeter should indicate 9 V or the diode should emit a bright red light.
6. Once the desired reaction has occurred, disconnect the battery. If standard wire were used instead of platinum-coated wire, the voltmeter would return to reading 0 V, as no battery is connected. However, due to the platinum acting as a catalyst, facilitating the recombination of hydrogen and oxygen, the voltmeter initially registers approximately 1 V. Over time, this voltage gradually diminishes until reaching 0 V.

EXPERIMENT 2: Assembly of fuel cell car from scientific kit and its operation

Required materials:

- Fuel Cell Car Science Kit - FCJJ-11[2] or similar

Procedure:

1. Follow the procedure from the manufacturer's instructions[3–9]

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EXERCISE 3: Modern batteries

DESCRIPTION

Modern batteries represent a pivotal cornerstone in powering our increasingly digital and mobile world. With advancements in technology, batteries have evolved from simple cells to complex energy storage systems, enabling various applications from smartphones to electric vehicles.

One of the key areas of development in modern batteries is energy density. Engineers continually strive to pack more energy into smaller and lighter packages, enhancing the runtime of portable devices while reducing their size and weight. Lithium-ion batteries have been at the forefront of this revolution, offering high energy density and rechargeability, making them the go-to choice for smartphones, laptops, and electric vehicles. However, sustainability has become a crucial focus in battery technology too. Researchers are exploring alternative materials and manufacturing processes to minimize the environmental impact of battery production and disposal. From recyclable materials, and abundant elements to solid-state electrolytes, efforts are underway to create batteries that are not only efficient but also eco-friendly.

In this respect, the future of batteries holds promise for even greater advancements. From solid-state batteries with enhanced safety and longevity to next-generation chemistries like lithium-sulfur, zinc-air, and sodium-ion, researchers are exploring diverse avenues to push the boundaries of energy storage technology. As technology continues to evolve, so too will batteries, driving innovation and shaping the landscape of our energy future.

DIDACTIC-METHODICAL COMMENTARY

This teaching unit is designed as step-by-step instruction. Students will find out more about principles, applications, and importance of Zinc-air batteries through experimental work and by using textbooks and other available sources.

EXAMPLE RESOURCES FOR EXPERIMENTAL WORK IN STEM ENVIRONMENT ON THE TOPIC "Zinc-air battery"

Resource 1: *Zinc-air battery. To assemble a Zinc-air battery using household materials and chemicals and gain insight into the fundamental principles of Zn-air electrochemistry.*

SAMPLE INVESTIGATIVE QUESTIONS ON THE TOPIC INTENDED FOR PROJECT ACTIVITIES IN STEM ENVIRONMENT:

1. How does the energy density of zinc-air batteries compare to other commonly used battery technologies?
2. What are the main advantages and disadvantages of zinc-air batteries in terms of cost, performance, and environmental impact?
3. How do variations in design and construction affect the efficiency and lifespan of zinc-air batteries?
4. How is a metal air battery similar to a fuel cell?
5. What role do catalysts play in improving the performance of zinc-air batteries, and how can their effectiveness be optimized?

6. What are the key challenges associated with the rechargeability of zinc-air batteries, and what strategies can be employed to overcome them?
7. How does the rate of oxygen diffusion influence the overall performance and energy output of zinc-air batteries?
8. What are the potential applications for zinc-air batteries in renewable energy storage systems, grid stabilization, and electric vehicles?
9. How do environmental factors such as temperature and humidity affect the operation and longevity of zinc-air batteries?
10. What advancements are being made in materials science to enhance the durability and stability of zinc-air battery components?
11. How can mathematical modeling and simulation be utilized to predict the behavior and optimize the performance of zinc-air batteries under different operating conditions?

Resource 1

ZINC-AIR BATTERY

BRIEF INFORMATION ABOUT THE LEARNING RESOURCE

Subjects	Chemistry, Physics, …
Age	Students
Time for execution	5 hours

This learning resource is designed to help gain a solid understanding of Zinc-air batteries, which are essential for sustainable energy storage. It explores the principles, applications, and importance of Zinc-air batteries in various fields such as renewable energy, environmental science, and engineering, making it accessible and relevant across diverse domains.

INTRODUCTION AND THEORETICAL BASIS[1]

This learning resource is meticulously crafted to offer a comprehensive understanding of zinc-air batteries through a diverse array of approaches. By integrating the following elements, it strives to provide an enriching educational journey aimed at facilitating the acquisition of knowledge and skills pertinent to zinc-air batteries. Key topics covered include:

<u>**Conceptual Understanding:**</u> Delving into the foundational principles underlying zinc-air batteries, the resource elucidates topics such as electrochemistry, cell design, and reaction mechanisms. This knowledge serves as a cornerstone for further exploration and comprehension.

Practical Applications: Providing insights into the real-world utilization of zinc-air batteries across various industries, including renewable energy storage, transportation, and consumer electronics. Through case studies and examples, learners gain an understanding of how these batteries are employed in practical scenarios.

Experimental Exploration: Offering hands-on experiments and demonstrations that enable learners to directly observe the behavior of zinc-air batteries. Through investigations into factors such as voltage output, efficiency, and performance under diverse conditions, participants develop a deeper comprehension of battery operation.

Problem-Solving Exercises: Presenting challenging problems and scenarios related to zinc-air batteries, the resource encourages learners to apply their knowledge to solve practical challenges. This approach fosters the development of critical thinking skills and reinforces conceptual understanding.

Collaborative Learning: Facilitating group activities, discussions, and collaborative projects that create an environment conducive to the exchange of ideas and experiences. Through peer interaction, learners deepen their understanding of zinc-air batteries while fostering teamwork and enhancing learning outcomes.

By incorporating these diverse elements, this learning resource endeavors to provide a holistic and engaging educational experience, empowering participants to gain comprehensive knowledge and skills relevant to zinc-air batteries.

RATIONALE FOR CONDUCTING THE EXPERIMENT

The rationale behind experimenting to build a simple zinc-air battery encompasses various facets, offering a comprehensive approach to learning. Firstly, it provides hands-on learning, offering participants a tactile and interactive experience that solidifies their understanding of electrochemistry and energy storage. As they engage in constructing the battery, learners gain firsthand insight into how its components collaborate to generate electricity. This practical engagement enhances comprehension by bridging theoretical knowledge with real-world application, reinforcing concepts like oxidation-reduction reactions, electron flow, and the roles of electrodes and electrolytes in galvanic cells. Moreover, building a zinc-air battery facilitates problem-solving and troubleshooting. Participants encounter challenges such as optimizing electrode materials, managing reaction rates, and enhancing electrical conductivity. Addressing these hurdles fosters critical thinking skills and encourages participants to devise innovative solutions, deepening their understanding of the underlying principles. Furthermore, zinc-air batteries are hailed for their potential in renewable energy storage due to their high energy density and cost-effectiveness. Constructing a zinc-air battery allows participants to explore the application of this technology in addressing energy storage challenges associated with renewable sources like solar and wind power, fostering an appreciation for sustainable energy solutions. Lastly, hands-on experiments like this promote interest and engagement in STEM fields. By applying STEM concepts in a practical setting, participants are inspired to pursue future endeavors in science, technology, engineering, and mathematics. This not only cultivates a passion for learning but also nurtures the next generation of innovators and problem-solvers in STEM-related careers.

INVESTIGATIVE TASKS TO BE EXECUTED

Investigative tasks to be executed for building a simple zinc-air battery are sa follows:

1. **Material Selection and Characterization:** Investigate different materials for the zinc anode and air cathode, considering factors such as reactivity, conductivity, and availability. Characterize the properties of selected materials, including surface area, porosity, and electrochemical performance, through techniques like scanning electron microscopy (SEM) and cyclic voltammetry.
2. **Electrolyte Optimization:** Explore various electrolyte solutions to enhance the performance and stability of the battery, considering factors such as pH, ionic conductivity, and compatibility with the chosen electrode materials. Investigate the effect of additives or buffering agents on electrolyte properties and battery performance through experimentation and analysis.
3. **Electrode Fabrication Techniques:** Investigate different methods for fabricating zinc and air electrodes, such as electrodeposition, screen printing, or inkjet printing, to optimize their morphology and performance. Explore the influence of electrode preparation parameters, including temperature, deposition time, and precursor concentration, on electrode structure and electrochemical properties.
4. **Assembly and Cell Design:** Investigate various cell designs and configurations to optimize the assembly process and maximize battery performance. Experiment with different separators and packaging materials to enhance cell stability and prevent electrolyte leakage or gas crossover.
5. **Performance Testing and Characterization:** Develop protocols for testing the electrochemical performance of the zinc-air battery, including methods for measuring voltage output, capacity, and cycle life. Investigate the effect of operating conditions such as temperature, humidity, and discharge rate on battery performance through systematic testing and analysis.
6. **Long-Term Stability and Durability Studies:** Conduct long-term stability and durability studies to assess the battery's performance under continuous operation and cycling conditions. Investigate degradation mechanisms and failure modes through post-mortem analysis, including examination of electrode morphology and chemical composition.
7. **Environmental Impact Assessment:** Investigate the environmental impact of the zinc-air battery, including the sustainability of raw materials, energy consumption during manufacturing, and potential for recycling or disposal. Evaluate the life cycle assessment (LCA) of the battery to understand its overall environmental footprint and identify opportunities for improvement.

Hypothesis: Using chemical and mechanical methods one can improve the performance of the Zn-air battery.

INVESTIGATIVE EXPERIMENT

EXPERIMENT 1: "Building simple Zinc-air battery"[2]

Required materials:

- Copper electrode
- Zinc electrode
- Alligator clips electrical test leads set of 2
- Multimeter and red diode
- Water cup
- Sodium chloride (about 25 g)
- Measuring cup, metric
- Bowl that can hold at least 500 mL
- Teaspoon
- Water
- Kitchen scale
- Hydrogen peroxide (3%) (about 20 mL)
- Straw
- Timer or watch with second hand

Procedure:[3]

1. Begin by preparing the saltwater electrolyte for your zinc-air battery. Dissolve 25 g of NaCl in a bowl filled with 0.5 L of water.
2. Label three water cups as #1–3 using a permanent marker. Conducting three trials concurrently ensures the accuracy and reproducibility of results.
3. Prepare your electrodes:
   a. Designate the Cu electrode as your cathode.
   b. Designate the Zn electrode as your anode.
4. Pour 150 mL of the prepared saltwater electrolyte into each labeled cup or jar.
5. Insert one Zn and one Cu electrode into each cup or jar, ensuring they are placed on opposite sides to face each other. Take care to prevent them from touching to avoid accidental short circuits.
6. Connect Alligator clips to electrical test leads, with the red lead connected to Cu and the black lead to Zn. The other ends should be connected to the red diode, which should illuminate.
7. You are now ready to test the functionality of your batteries. Test each battery successively with a multimeter under the following conditions, disconnecting the diode and connecting the multimeter:
   a. No addition to the electrolyte
   b. Continuous stirring
   c. Continuous blowing bubbles with a straw

d. Addition of 5 mL of 3% H_2O_2
e. Addition of 5 mL of 3% H_2O_2 plus continuous stirring

8. Measure the open-circuit voltage and short-circuit current of each zinc-air battery. Begin with the first trial and proceed with the other two. These measurements provide the highest voltage and current that your battery can supply, although note that it cannot simultaneously provide both.

REFERENCES

Li, Y.; Dai, H. Recent Advances in Zinc-Air Batteries. *Chem. Soc. Rev.* **2014**, *43* (15), 5257–5275. https://doi.org/10.1039/c4cs00015c.

How to Make a Battery with Metal, Air, and Saltwater https://www.sciencebuddies.org/science-fair-projects/project-ideas/Chem_p107/chemistry/make-a-battery-with-metal-air-and-saltwater#procedure.

Procedure, E. How to Make a Battery with Metal, Air, and Saltwater | Science Project. **2021**.

Example: Sustainable Technologies in Science Education- Part 2. Teaching Unit via Project-Based Learning

Description of innovative Green STEAM teaching/learning unit

Educational level (students' age): Master Level 2nd Cycle

Subject: Sustainable Technologies in Science Education

Topics: Sustainable Technologies

Curriculum objectives:

- Understand Sustainable Energy Concepts
- Understand the principles of hybrid renewable energy systems.
- Design and analyse integrated systems combining multiple sustainable technologies.
- Define and explain the principles of sustainable energy.
- Identify the environmental impacts of traditional energy sources.
- Describe the working principles of hydrogen fuel cells.
- Analyse the advantages and challenges of hydrogen fuel cell technology.
- Demonstrate the ability to design and construct a basic hydrogen fuel cell.
- Explain the process of electrolysis for hydrogen production.
- Evaluate the efficiency and practical applications of electrolysers.
- Compare and contrast lithium-ion batteries with emerging battery technologies.
- Analyse the environmental and economic implications of different battery types.
- Demonstrate the ability to design and test a battery system.
- Understand the concept of electrochemical microreactors.
- Explain the principles of photovoltaic energy conversion.
- Analyse the efficiency and limitations of solar photovoltaic systems.
- Design and optimize a photovoltaic system for a given scenario.
- Describe the working principles of wind turbines.

Key words: green STEM, sustainable technologies, project-based learning

Learning tools: learning management system (e.g. Moodle), collaboration platform (e.g. Microsoft Teams), literature databases (e.g. Scopus, Web of Science, Google Scholar, ERIC), presentation, documentation, and spreadsheet software (e.g. PowerPoint, Word, Excel), graphics tool (e.g. Canva), tools for school experimental data collection (e.g. Vernier sensors) etc.

Literature resources for students

obligatory: /

additional:

Dinçer, İ., & Erdemir, D. (2023). *Introduction to Energy Systems*. John Wiley & Sons.

Ferk Savec, Vesna (2010). *Projektno učno delo pri učenju naravoslovnih vsebin : učbenik*. Maribor: Fakulteta za naravoslovje in matematiko.

Hacker, V., & Mitsushima, S. (Eds.). (2018). *Fuel cells and hydrogen: from fundamentals to applied research*. Elsevier.

He, G. (2024). *Electrochemical Energy Storage Technologies Beyond Li-ion Batteries*.
Korthauer, R. (Ed.). (2018). *Lithium-ion batteries: basics and applications*. Springer.
Monconduit, L., & Croguennec, L. (2021). *Les batteries Na-ion*. ISTE Group.

Literature resources for (future) teachers

Obligatory/additional:

Dinçer, İ., & Erdemir, D. (2023). *Introduction to Energy Systems*. John Wiley & Sons.
Ferk Savec, Vesna (2010). *Projektno učno delo pri učenju naravoslovnih vsebin : učbenik*. Maribor: Fakulteta za naravoslovje in matematiko.
Hacker, V., & Mitsushima, S. (Eds.). (2018). *Fuel cells and hydrogen: from fundamentals to applied research*. Elsevier.
He, G. (2024). *Electrochemical Energy Storage Technologies Beyond Li-ion Batteries*.
Korthauer, R. (Ed.). (2018). *Lithium-ion batteries: basics and applications*. Springer.
Monconduit, L., & Croguennec, L. (2021). *Les batteries Na-ion*. ISTE Group.

Teaching method(s): project-based learning, experimental work

THEORETICAL BACKGROUND

THEORETICAL BACKGROUND

The course for teachers combines contents, tools and good practices that involve PBL, IBL, and Engineering Design-Based innovative methodologies with a hybrid approach.

A. In Green STEM program tools, activities start with authentic problems. Authentic problems also serve as significant incentives for students to engage in inquiry-based and problem-based learning. Authentic problems define the types of problems that can support students in scientific inquiry skills (Burrows et al., 2016), address the real-life working styles of scientists and researchers in science-related fields (Hsu et al., 2010), and how science is applied (van Eijck & Roth, 2009). Therefore, the activities exemplified in the Green STEM project include authentic research problems that can support students' inquiry by focusing on hands-on and minds-on engagement.

For example, the activity titled "TOPIC B.1: Atmospheric Water Harvesting" starts with an authentic problem related to harvesting water from the atmosphere, also known as atmospheric water harvesting, to obtain usable water by extracting moisture from the air. The activity aims to have students solve problems related to water procurement in areas experiencing water scarcity and provide a potential solution for regions with limited access to freshwater sources. Various techniques such as condensation, dew collection, fog harvesting, and Atmospheric Water Generators (AWGs) need to be researched by students in the activity, and they should acquire knowledge and test them in laboratory environments.

B. In Green STEM program tools, the design and engineering process is uniquely supported and enhanced. Current methodologies and approaches on engineering design processes and design-based learning are clearly defined in activity flows and implementation processes. The theoretical content under the title "TOPIC A.5: Green STEM and Future of Works and Skills in the Green Industry" extensively emphasizes the importance of design and engineering professions within green careers. During workshops or seminars organized as part of the dissemination process of the Green STEM model, the activity artifacts, presentation, and discussions of Green STEM project designs related to TOPIC 8-14 form a significant discussion topic on design and engineering. Materials and observation protocols developed for teachers have benefited from the innovative methods of design and engineering from Gunbatar et al. (2022), Dare et al. (2021) and Ong et al. (2023).

C. Laboratory studies and processes found in the Green STEM program tools support innovation in a way that enables students to understand green mathematics, science, and engineering concepts. Inquiry-based learning is an instructional approach tailored for learning through laboratory processes. In activities developed for the Green STEM program, students are encouraged to interact through exploration and high-level inquiry (mostly open inquiry tasks), establishing real-world connections. Professional development tools prepared for teachers encourage them to guide the instructional process in various roles that can be expressed as diagnostician, motivator, innovator, experimenter, researcher, modeler, and learner (Crawford, 2000). Thus, an instructional approach that encourages students to engage in problem-solving and experiential learning is adopted. In activities, students are supported in their active participation or motivation in at least one of the processes such as questioning, designing, data collection, reaching conclusions, or communication of learning, as defined by Minner et al. (2010):

- the presence of science content,
- the student's active involvement in science content,
- their responsibility for learning through at least one of the processes of questioning, designing, data collection, reaching conclusions, or communication, supporting their active participation or motivation.

D. The project activities in the Green STEM program tools support evidence-based (data-driven) thinking. This also provides an approach supported by "The Informed Design Teaching and Learning" defined by Crismond & Adams (2012) and IBL. Evidence is used for students to evaluate, revise, and improve their designs. The stages of "Evaluation of the Product/Solution," "Improvement," and "Reflecting/Sharing" included in the activity flows are designed precisely for this purpose. This aims to ensure that the designs students present in green STEM activities have consistent and precise (usable) data. When students see how and why the information obtained in the designs is used, they experience a "eureka" moment. This also initiates an endless design cycle for them. By continually developing, reassessing, and improving their designs based on real evidence and observations, students can reach innovative final designs. Crismond & Adams (2012) published valuable research presented for an understanding that can be adopted in activities for the informed design teaching and learning matrix.

Example: Biomimicry Nanofabrics & Environmental Industry Practices

Description of innovative Green STEAM teaching/learning unit

Educational level (students' age): Middle School

Subject: Green STEM

Topics: Biomimicry Nanofabrics & Environmental Industry Practices

Curriculum objectives:

Science objectives:

- Observes examples of water-repellent fabrics in nature through the lotus effect,
- Gains fundamental knowledge in material science and nanotechnology by learning the principles of nanotechnology in water-repellent fabrics,
- Acquires practical experience in understanding the properties of water-repellent fabrics and exploring the scientific basis of the lotus effect.

Engineering objectives:

- Solves engineering problems by focusing on the design of nano water-repellent fabrics,
- Enhances engineering skills by providing opportunities to experience design thinking, prototyping, and improvement processes.

Technology objectives:

- Enhances technology skills by using various technological tools and materials to transform ideas into tangible fabric prototypes,
- Develops technology skills by gaining experience in using technological tools to evaluate and test water-repellent fabrics.

Mathematics objectives:

- Improves mathematical thinking by using measurement, calculation, and data analysis skills in the design process,
- Understands and applies mathematical methods used to evaluate the performance of water-repellent fabrics.

Art objectives:

- Develops art skills by using creative thinking and aesthetic understandings in the design process,
- Enhances art skills by providing opportunities to express design ideas artistically and aesthetically improve prototypes.

Related GREEN STEM objectives:

- GD2. Clean and Circular Economy
- GD2.d. Innovative Practices for Sustainable Production and Reduction of Carbon Emissions and Greenhouse Gas Emissions in the Textile and Leather Sectors.

Key words: Biometric concept, Lotus effect, Nano water repellency, Nano hydrophobic fabrics

Learning tools:	Student worksheet 1, 2, 3	Wax, Vaseline, fabric wax, Superhydrophobic coating (Spray), Various fabrics, Test materials (such as plastic bottles, sponges, droppers, wooden sticks, measuring equipment, etc.)

Literature resources for students

Arabacioglu, S. (2022). Can nanotechnology keep us dry in the rain: An inquiry-based activity to help students improve their investigation skills. International Journal of Technology in Education and Science (IJTES), 6(3), 410-426. https://doi.org/10.46328/ijtes.395

Literature resources for (future) teachers

Arabacioglu, S. (2022). Can nanotechnology keep us dry in the rain: An inquiry-based activity to help students improve their investigation skills. International Journal of Technology in Education and Science (IJTES), 6(3), 410-426. https://doi.org/10.46328/ijtes.395

Blonder, R., & Mamlok-Naaman, R. (2016). Learning about teaching the extracurricular topic of nanotechnology as a vehicle for achieving a sustainable change in science education. International Journal of Science and Mathematics Education, 14(3), 345–372. https://doi.org/10.1007/s10763-014-9579-0

Ghattas, N. I., & Carver, J. S. (2012). Integrating nanotechnology into school education: A review of the literature. Research in Science and Technological Education, 30(3), 271–284. https://doi.org/10.1080/02635143.2012.732058 *Mandrikas, A., Michailidi, E., & Stavrou, D. (2020). Teaching nanotechnology in primary education. Research in Science and Technological Education, 38(4), 377–395. https://doi.org/10.1080/02635143.2019.1631783* *Sakhnini, S., & Blonder, R. (2016). Nanotechnology applications as a context for teaching the essential concepts of NST, International Journal of Science Education, 38(3), 521-538. https://doi.org/10.1080/09500693.2016.1152518*	
Teaching method(s):	Problem-Based Learning, Inquiry-Based Learning, Project-Based Learning, Design Thinking and Engineering Design, Hands-on Science, Applied Learning, Technology-Enhanced Learning.

Scenario of Green STEAM teaching/learning unit

Phase	Required time	Teachers' activity	Students' activity
Recalling the Known and Experiences	30 min	The teacher can start by grabbing students' attention and introducing the topic with an interesting question or story. For example, they might ask students about the challenges they face on a rainy day or how they feel in the rain. Then, they can explain to the students what water-repellent fabrics are and how they work. By describing the features and benefits of these fabrics, they help students better understand the topic. By illustrating different application areas of water-repellent fabrics with examples, the teacher assists students in comprehending the significance of these fabrics in daily life. Providing examples of water-repellent fabrics or supporting with visuals gives students a more concrete idea. Djital araç – Yağmurluklu bir insan görseli üzerinden tartışma….	Students can share what kind of experiences they have had in rainy weather and how water behaves when they come into contact with rain. A discussion is initiated based on these experiences. Students are asked questions to understand why and how water-repellent fabrics work. For example, what are the characteristics of water-repellent fabrics? What are the advantages of water repellency fabrics? Students can research the different application areas of water-repellent fabrics. For example, raincoats, sportswear, outdoor materials, etc. They can discuss in groups the importance of increasing the functionality and comfort of water-repellent fabrics. Each group can address a specific application area and discuss the advantages these fabrics provide.
Research & Questions	1 hour	Students are instructed to obtain leaves from water lilies, taro plants, members of the Brassicaceae family, lady's slippers, ginger plants, and garden roses. They are asked	Students examine leaves obtained from the specified plant species under a magnifying glass. They take notes on the observed patterns or structures.

		to closely examine the leaves under a magnifying glass and discuss the patterns or structures they observe. Students are asked to place a droplet of water on the leaf surface and observe the behavior of the water droplets, explaining how they behave. They are encouraged to compare the behavior of water droplets on different plant leaves and discuss possible reasons, prompting discussions. Students are encouraged to record their observations and experiment results on **Worksheet 1.** They are also encouraged to further deepen their research within specific frameworks of questions. They are asked to identify the micro/nano structures on the surface of lotus leaves and discuss their water-repellent role. They are prompted to think about how nanostructures reduce the contact area between water droplets and the leaf surface. Discussions are encouraged on why water droplets on lotus leaves form nearly spherical shapes and obstacles to spreading are addressed. Students are encouraged to discuss potential everyday applications of mimicking the surface properties of lotus leaves. They are also encouraged to research whether there are other examples in nature with water-repellent strategies similar to lotus leaves.	They place a drop of water on the leaf surface. They observe the behavior of the water droplets and explain what is happening. They compare the behavior of water droplets on different plant leaves and discuss the differences. They record their observations and experimental results on **Worksheet 1.** They deepen and discuss their research within specific questions. They describe micro/nano structures and discuss their water-repellent role. They examine the shape and behavior of water droplets on the leaf surface and consider the reasons behind them. They contemplate practical applications of mimicking the characteristics of lotus leaves. They research if there are other plant examples in nature with water-repellent strategies.
Generate-Solution Design:	1 hour	Students are encouraged to brainstorm in groups to design their own nano-hydrophobic fabrics. Each group brainstorms by	Students discuss examples to consider potential applications in everyday life. For instance, they are

		discussing different design ideas and features. It encourages students to exchange ideas from different perspectives. Students are encouraged to fill out **Worksheet 2** in groups. They are assisted in identifying design ideas and features, and the design process is guided.	encouraged to discuss how products such as raincoats, water-resistant bags, or self-cleaning surfaces could be utilized. Students are given the freedom to choose the materials they will use for the product they design. They select materials such as wax, superhydrophobic coatings, and various fabrics. With the materials they choose, they create a simple prototype. This prototype helps them see how the design works and allows them to make improvements. During the design process, they focus on the following design criteria: **Design Criteria:** • Focuses on reducing environmental impacts and adhering to sustainability principles in material selection and use. • Designed for potential real-life applications (e.g., raincoats, waterproof bags, or self-cleaning surfaces, etc.). • Creates simple prototypes of their products using environmentally friendly materials (such as wax, vaseline, paraffin, wax, superhydrophobic coatings, different fabrics (feather, parachute, upholstery), etc.).
Prototype Creation and Testing:	1 hour	Students are provided with various fabric samples, spray coatings, brushes, and other necessary materials. They are encouraged to use these materials to bring their own ideas to life. Guidance is provided to help them materialize their ideas, and support is given as needed.	Students transform their own ideas into tangible prototypes and test them. They use various materials such as fabric samples, spray coatings, brushes, etc., to do this. They create prototypes using their own ideas and fill out **Worksheet 3**. They note down what they did at each step, which

		Students are encouraged to fill out **Worksheet 3** to document the prototype creation process step by step. They are prompted to take notes on what they did at each step, what materials they used, and what results they achieved. **Water Repellency Tests:** Students are given the opportunity to test the water repellency of their fabric prototypes and evaluate the results. They are guided in planning various experiments to test the water repellency of fabric prototypes. General information is provided on how to conduct water-based experiments, with an emphasis on controlled experimental practices. Students are encouraged to record the data, observations, and results they obtain during the experiments. They are provided with the opportunity to compare the performance of fabric prototypes with regular fabric samples and analyze the results.	materials they used, and what results they obtained. **Water Repellency Tests:** Students have the opportunity to test the water repellency of their fabric prototypes and evaluate the results. They gain general knowledge about how water-based experiments are conducted and plan controlled experiments. They record the data, observations, and results obtained during the experiments. They compare the performance of fabric prototypes with regular fabric samples and analyze the results.
Product Introduction, Discussion, and Evaluation	30 min	Students are encouraged to prepare a presentation to introduce the prototypes of nano hydrophobic fabric. They are asked to decide on one of the various Web 2.0 tools such as Prezi, PowerPoint, Canva, etc., that they can use for this purpose. Students are encouraged to share on the following topics during the presentation: • Introducing the prototypes to the class and emphasizing the biomimicry principles used. • Presenting the test results and	Each student or group presents their own prototypes through a suitable Web 2.0 tool. They provide detailed information about the biomimicry principles used. Within the class, students examine each other's prototypes. They discuss the advantages and disadvantages of each prototype and exchange ideas about the challenges encountered in applying biomimicry principles. They review the designs of other groups and compare them with their own prototypes. They determine

		providing evidence of the effectiveness of each design. • Sharing the encountered challenges and lessons learned about water-repellent fabrics. For evaluation purposes, students are expected to: • Compare their prototypes with those of other groups. • Evaluate which biomimicry approach is more effective. • Provide suggestions on how to improve the prototypes. • Engage in discussions on how to use biomimicry principles more effectively.	which features are more successful. Based on the feedback received from other groups, they discuss how they can improve their prototypes. They speculate on how to apply biomimicry principles more effectively.	

Example: Atmospheric Water Harvesting

Description of innovation Green STEAM teaching / learning unit

Educational level (students ' age): Middle School – High School

Subject : Green STEM

Topics : Atmospheric Water Harvesting

Curriculum objectives :

Science Learning Outcomes:

- Students understand the water cycle (Understanding)
- Students understand the concept of obtaining water from air by condensation (Understanding)
- Students learn the importance of water conservation and discover sustainable water solutions (Comprehension).
- They apply basic science principles to make the prototype more efficient (Application)
- Evaluates the methods of obtaining water from the atmosphere (Evaluation)

Engineering Learning Outcomes:

- Students design and build a model device to collect water from the air.
- In the design and construction process, students use critical thinking, problem solving and teamwork skills.
- Learns how to calculate the efficiency of the device.

Technology Learning Outcomes:

- Students measure and analyze the humidity in the air and in the prototype using sensors and data collection devices (scales, thermometers, etc.) .
- Students learn different atmospheric water harvesting technologies and their use.
- Students present their model devices to the class (with elements such as infographics , graphs, etc.) and show that they understand the harvesting water from the atmosphere by explaining it .

Mathematics Learning Outcomes:

- It shows the drought in its regions in the form of a regional rainfall amount-month graph or similar graphs.
- Students analyze the water demand in the region with mathematical models and calculate the amount of water that the required water harvesting device must provide.
- They calculate the efficiency of the vehicle.

Art Learning Outcomes:

- Students pay attention to aesthetic values in the design of the water harvesting device and use creative, motivative elements when developing the prototype .

Entrepreneurship

- Determines societal needs and comes up with creative solutions to address them.
- Makes use of mass communication platforms to advertise the created goods.
- Uses written, visual, and spoken communication techniques to clearly and consistently convey his thoughts and discoveries to the professional target audience.

Green STEM achievement:

- Suggests using environmentally friendly green scientific techniques to reduce the impact of human activity on the environment in order to address societal issues or demands.

21st Century Skills

- Improves problem solving skills.
- Improves collaborative working skills.
- Improves his/her sensitivity to the environment and the world he/she lives in increases.

THE NATURE OF SCIENCE (OR SCIENTIFIC INQUIRY):

- Creates or revises scientific explanations based on valid and reliable data or evidence obtained from sources (including students' own experiments).
- Conducts research and/or evaluates and/or revises the experimental design to find a solution to the problem and obtain data.

Related Green Deal (Green Deal) Strategies:

GD1. Climate Change, Environment and Biodiversity : The Purpose of Regulating Climate Change, Carbon Emission and Greenhouse Gas Emissions

Theoretical Information

One of the biggest worldwide issues affecting many regions of the world is water scarcity. The lack of freshwater resources that makes it difficult for the populace to achieve their basic water needs is referred to as water scarcity. There are several factors contributing to this shortage, including human and natural influences. Due to prolonged droughts and erratic rainfall brought on by climate change, there is now less water available. Furthermore, pollution, population expansion, and inadequate water management exacerbate this issue. Many arid and semi-arid nations today, including those in Africa, the Middle East, and some regions of Asia, struggle with a lack of water. These areas experience significant difficulties in accessing clean water, resulting in deterioration of food security and public health, agricultural restrictions and negative effects on socioeconomic growth. Efforts to address water scarcity include implementing sustainable water management strategies, promoting water conservation practices, and investing in water purification and desalination technologies.

Getting water from air, also known as atmospheric water harvesting , is a process that involves extracting moisture from the atmosphere to obtain usable water. This innovative approach addresses the problem of water scarcity and offers a potential solution for regions with limited access to freshwater resources. Various techniques are used to extract water from air, such as condensation, dew harvesting, fog harvesting and atmospheric water generators (AWGs). Condensation refers to the cooling of air to cause water vapor to condense into liquid form. Dew collectors use large surfaces to capture dew droplets that form during the night. Fog collectors use nets to capture water droplets from passing fog. AWGs use cooling or drying methods to remove water vapor from the air, which is then condensed and filtered to produce drinkable water. These methods are seen as promising opportunities for sustainable water supply in arid, semi-arid or coastal regions, as they use moisture contained in the air to create freshwater sources. Ongoing research and technological advances in atmospheric water harvesting have great potential to alleviate water scarcity problems worldwide.

Key words :

Climate change , water scarcity , atmospheric water harvesting , condensation , moisture , dew , fog , biomimicry , passive cooling methods , adsorbents

Learning tools :	**Equipment :**
Worksheets Digital Tools	white papers Colorful pencils Laptop and projector for multimedia screenings Construction materials (e.g. plastic bottles, sponges, rubber bands, different perforated fabrics, scissors, tape, glue, wooden sticks, cardboard boxes, cardboard, etc.) thermometers Hygrometer water vapor diffuser water spray bottle Glasses or containers to collect water Different substances on which condensation will occur Mirror Piece of Metal

Literature resources for teachers

obligatory :

BİLDİREN, Ş., & SARGINCI, M. (2022). An Alternative Solution Proposal to Water Shortage Due to Climate Change: Atmospheric Water Harvesting. *Duzce University Ornamental and Medicinal Plants Botanical Garden Journal* , *1* (1), 21-35.

Sleiti, A.K., Al-Khawaja, H., Al-Khawaja, H., & Al-Ali, M. (2021). Harvesting water from air using adsorption material–Prototype and experimental results. *Separation and Purification Technology* , *257* , 117921.

Villacrés, D.C., Carrera Villacrés, J.L., Braun, T., Zhao, Z., Gómez, J., & Carabalí, J.Q. (2020). Fog harvesting and IoT based environment monitoring system at the Ilalo volcano in Ecuador. *International journal on advanced science, engineering and information technology* , *10* (1), 407-412.

Verbrugghe, N., & Khan, A.Z. (2023). Water harvesting through fog collectors: a review of conceptual, experimental and operational aspects. *International Journal of Low-Carbon Technologies* , *18* , 392-403.

Jarimi, H., Powell, R., & Riffat, S. (2020). Review of sustainable methods for atmospheric water harvesting. *International Journal of Low-Carbon Technologies* , *15* (2), 253-276.

Bilal, M., Sultan, M., Morosuk, T., Den, W., Sajjad, U., Aslam, M.M., ... & Farooq, M. (2022). Adsorption-based atmospheric water harvesting: A review of adsorbents and systems. *International Communications in Heat and Mass Transfer* , *133* , 105961.

additional :

Below are links to websites containing the drought and its effects in our region. It is recommended that you read these sites first, as they can be used as a guide in your design:

https://www.cnnturk.com/turkiye/kesanda-2-5-aylik-su-kaldi-kararlara-uymayanlara-ceza?page=6

https://www.aa.com.tr/tr/ekonomi/trakyada-kuraklik-ayciceginde-buyuk-verim-kaybina-neden-oldu/3025824

https://www.hurriyet.com.tr/gundem/edirnede-kuraklik-alarmi-belediye-baskani-barajin-ortasindan-cagri-yapti-42346675

https://www.ntv.com.tr/galeri/turkiye/kuraklik-35-yildir-tarim-arazisinin-sulandigi-goleti-de-vurdu,Bp9Q9JrIj0m-tL6LmXQWug/LSlq7PJ8lkCXx7u_GkQsLw

https://www.edirne.bel.tr/icerik/baskan-gurkan-son-63-yilin-en-kurak-subat-ayini-gecirdik

https://www.cumhuriyet.com.tr/turkiye/meteorolojinin-verileri-gozler-one-serdi-edirnede-korkutan-goruntu-ciftci-ekim-yapamadi-1997363

https://www.haberturk.com/edirne-haberleri/32896574-edirnede-kuraklik-kanola-ekimini-olumsuz-etkiledi
Literature resources for students obligatory : BİLDİREN, Ş., & SARGINCI, M. (2022). An Alternative Solution Proposal to Water Shortage Due to Climate Change: Atmospheric Water Harvesting. *Duzce University Ornamental and Medicinal Plants Botanical Garden Journal* , *1* (1), 21-35. Sleiti, A.K., Al-Khawaja, H., Al-Khawaja, H., & Al-Ali, M. (2021). Harvesting water from air using adsorption material–Prototype and experimental results. *Separation and Purification Technology* , *257* , 117921. Villacrés, D.C., Carrera Villacrés, J.L., Braun, T., Zhao, Z., Gómez, J., & Carabalí, J.Q. (2020). Fog harvesting and IoT based environment monitoring system at the Ilalo volcano in Ecuador. *International journal on advanced science, engineering and information technology* , *10* (1), 407-412. Verbrugghe, N., & Khan, A.Z. (2023). Water harvesting through fog collectors: a review of conceptual, experimental and operational aspects. *International Journal of Low-Carbon Technologies* , *18* , 392-403. Jarimi, H., Powell, R., & Riffat, S. (2020). Review of sustainable methods for atmospheric water harvesting. *International Journal of Low-Carbon Technologies* , *15* (2), 253-276. Bilal, M., Sultan, M., Morosuk, T., Den, W., Sajjad, U., Aslam, M.M., ... & Farooq, M. (2022). Adsorption-based atmospheric water harvesting: A review of adsorbents and systems. *International Communications in Heat and Mass Transfer* , *133* , 105961. *additional :* **--Below are links to websites containing the drought and its effects in our region. It is recommended that you read these sites first as they can be used as a guide in your design.** https://www.cnnturk.com/turkiye/kesanda-2-5-aylik-su-kaldi-kararlara-uymayanlara-ceza?page=6 https://www.aa.com.tr/tr/ekonomi/trakyada-kuraklik-ayciceginde-buyuk-verim-kaybina-neden-oldu/3025824 https://www.hurriyet.com.tr/gundem/edirnede-kuraklik-alarmi-belediye-baskani-barajin-ortasindan-cagri-yapti-42346675 https://www.ntv.com.tr/galeri/turkiye/kuraklik-35-yildir-tarim-arazisinin-sulandigi-goleti-de-vurdu,Bp9Q9JrIj0m-tL6LmXQWug/LSlq7PJ8lkCXx7u_GkQsLw https://www.edirne.bel.tr/icerik/baskan-gurkan-son-63-yilin-en-kurak-subat-ayini-gecirdik https://www.cumhuriyet.com.tr/turkiye/meteorolojinin-verileri-gozler-one-serdi-edirnede-korkutan-goruntu-ciftci-ekim-yapamadi-1997363 *https://www.haberturk.com/edirne-haberleri/32896574-edirnede-kuraklik-kanola-ekimini-olumsuz-etkiledi*
Teaching method (s): problem - based learning , inquiry-based research , project-based learning , design thinking , biomimicry , engineering design

Scenario of Green STEAM teaching / learning unit

Phase	Required time	Teachers ' activity	Students ' activity
Defining the Problem	1 hour	For the activity that aims to develop a prototype for water harvesting from the atmosphere, It is advised that you project the file from	-Students give examples of water scarcity in the region they live in and its effects on society.

		APPENDIX 1 onto the classroom board to begin the lesson by talking about the value of water and the challenges associated with its scarcity before beginning the activity (In addition, visuals or films showing water scarcity and its effects on communities can be shown if desired.) -Students are expected to give examples of water scarcity in the region they live in and its effects on society. -As the presentation progresses, ways to obtain clean water are discussed. - Discusses the concept of air extraction as a potential solution to water scarcity. -Explain that the class will learn about condensation and design a model device to collect water from the air. -For the activity, students are divided into groups of 2-3 people. -The problem is given to the students by projecting it on the board and printed on the worksheet. -Different methods of atmospheric water harvesting are recommended in the plan below, focusing only on **passive cooling technologies** to manage the process well. In cases where there is no time limit, all atmospheric water harvesting technologies can be focused on. -Cards are created and printed for each of the atmospheric water harvesting technologies. (Cards are given in APPENDIX 2) -Groups are allowed to choose one of the atmospheric water harvesting	- They discuss ways to obtain clean water - They discuss the concept of water harvesting from the air. - They are divided into groups of 2-3 people. - The students are presented with the problem scenario and given the chance to discuss it among themselves to gauge their understanding of the issue. -Groups choose one of the atmospheric water harvesting technologies by lottery and are asked to prepare a prototype in accordance with that technology. - What is known about the problem situation and the resulting opinions are recorded as a group **in Student Worksheet 1, where the problem is also given in writing** .

		methods by drawing lots and focus on it. - The aim of the activity is for students to understand the summarized problem situation, and in order to reinforce student experiences, they are encouraged to think about the questions under the subheading of Remembering **Known Things and Experiences** in **Student Worksheet 1 .**	
Remembering and Research	**1 hour**	In order to reveal their prior knowledge about the problem and possible solution(s), students are asked to write down what they know and their experiences within the framework of the following questions in **the Remembering What is Known and Experiences section** of **Student Worksheet 1** . - What is drought? What are the effects that cause drought? -What might have caused the drought in a particular region? -What effects can drought have on the environment, agriculture and people? -How does drought affect agricultural products? Which agricultural products are most affected in your region? -What solutions can be suggested to combat drought? -What suggestions can you make about what individuals or societies can do to cope with drought? -What is condensation? How does it happen? -Which factors affect the formation of water vapor in the atmosphere?	Regarding the problem situation, the information given in **the Remembering What Is Known and Experienced** section is given. Information and experiences regarding the questions are recorded as a group **in Student Worksheet 1** . The answers found by doing the necessary research to the questions that need to be researched in **Student Worksheet 1 are recorded in appropriate places. It is stated** to cite their sources.

		Students are asked to consider what questions they need to find solutions to in order to solve the problem under the category "What Needs to be Researched". How, for instance, can water be extracted from the atmosphere? Which tools and techniques are available? -What are the advantages of collecting atmospheric water for the environment and society? What obstacles or restrictions exist when trying to get water from the atmosphere? Students are expected to conduct research and document their findings in Student Worksheet 1 for questions like these. They are cautioned to cite their sources.	
Design and Creation	**2 hours**	**Solution Producing-Product design** At the stage , students to design wanted of the product to carry required features , design criteria aspect In **Student Worksheet 2** is given . **Design Criteria :** **Weather and Climate Conditions:** Examine your region's climate to determine the best times and locations for water gathering. (You can get an idea by drawing a rainfall-month graph for your area.) **Water Need:** Determine the water need in your region and aim to produce enough water to meet this need. **Portability and Easy Installation:** The prototype should be aimed to be easy to install and portable, as this	All suggestions for problem-solving within the parameters of the specified design standards and technology are made and documented in Student Worksheet 2. Group discussions are used to choose the best idea. The supplies needed to put the chosen idea into practice are identified. A detailed explanation of the product's design is provided, and an engineer-quality sketch is created using precise dimensions. They are cautioned to cite their sources.

		will provide flexibility for use in different places at different times. **Savings and Efficiency:** The aim should be to produce more water by consuming less energy. **Material Selection and Cost:** Aim to choose sustainable and cost-effective materials. (In which geometry and in which material does condensation occur more? Which materials have high water retention capacity? Which materials are adsorbents?) **Reliability and Environmental Impacts:** Aim for a design that will keep the vehicle's harmful effects on the environment to a minimum. The design criteria are explained to the students. Students are encouraged to brainstorm, examine the design requirements and the technology they select, and provide various solutions to the challenge. Examine the drawings produced by each group and offer assistance as needed. Remind us how crucial it was to construct the model with consideration for elements like surface area, insulation, airflow, and condensate collection. Make students realize that there may be more than one correct path to the solution. Have them record all their ideas in Student Worksheet 2. Afterwards, students are directed to choose the most appropriate one among the ideas and use it to develop a prototype. In order to improve decision-making	

		skills, "Which of the ideas did you decide to use and why?" They are made to think by asking questions. At this stage, students are expected to decide what kind of prototype they will make within the design criteria. They are urged to determine the supplies required to carry out the selected proposal. The supplies needed for the exercise are all ready in advance and given to the pupils in large quantities. Students should be asked to describe the design of the product in detail and draw it with measurements like an engineer.	
Prototype Creating and Testing	5 hours	In the Prototyping and Testing phase, students are guided to create a prototype of the product by implementing their plans and using appropriate materials. They are asked to test the resulting product. In this process; -Students are asked how they will determine the amount of condensation that will occur in the prototype. (Students can determine the initial mass of the prototype and the amount of water collected by measuring the mass from time to time during condensation. Or they may consider collecting the water in a container and measuring its mass. Or they may suggest using a hygrometer.) - Students are encouraged to use the information they have researched to think about the conditions under which	A prototype of the product is created by applying the drawing and using appropriate materials. The resulting product is tested by collecting water from the atmosphere. In this process; -It is recommended to generate ideas on how to collect condensation. -Factors that will accelerate condensation are discussed. -A graph is created against the amount of water collected. -Data is interpreted.

		condensation will occur more quickly. While testing the product, it should be realized that they can provide humidity with a humidity-producing diffuser and shorten the process. -Students are asked to spend a period of 4-5 hours (or more if the conditions are appropriate) to collect water and to determine the amount of water collected in certain periods of time and to draw graphs of the data they obtain. - They are asked to think about how to calculate the efficiency of the prototype and use what they have researched.	
Product Introduction, Discussion And Evaluation	1 hour	For Product Promotion, Discussion and Evaluation stage, -Each group is asked to explain to the class the features of their model devices and how water is obtained and collected. - Other students are encouraged to ask questions and provide constructive feedback. - A class discussion is led about the challenges encountered during the planning and construction phases. - The applicability and limitations of real-life water harvesting devices are discussed. - The importance of long-term water solutions and the contribution of STEM to the solution of global problems are emphasized.	A presentation is prepared by planning how the product will be introduced. The product of each group is evaluated under the guidance of the teacher and with the participation of all groups. Based on the class evaluation, the class discusses how much the product solves the problem. In addition, the advantages and disadvantages of different design products produced by the groups are discussed with the participation of the whole class.

		- A concept map or diagram is created by combining the methods worked by each group according to the methods of obtaining water from air.	
Product Development	1 hour	Students are asked to discuss among themselves the changes they plan to improve the product and record them in Student Worksheet 2.	In order to improve the product, it is discussed in groups and changes that can be made to the product and how the product will be more efficient are planned and recorded in Student Worksheet 2.
What I learned sharing	1 hour	Students are asked to share what they have learned by discussing it within the framework of the questions written below and record it in Student Worksheet 3. - Write down what you learned during the preparation and design phase of the prototype. - Write down what you learned during the testing phase of the prototype. - Write down what you learned during the product introduction phase of the prototype. - Write down what you learned during the product development phase of the prototype.	By having group discussions based on Student Worksheet 3's questions, the lessons are addressed and documented.

Example: Solar Powered Food Dryer

Green STEM Teaching Activity: Solar Powered Food Dryer

Educational Level: Middle School – High School (10 – 16 years old)

Subject Area: Green STEM

Activity Name: Solar Powered Food Dryer

Gains:

Science Gains:

• He discovers that light can be absorbed by matter as a result of its interaction with matter.
• Gives examples of innovative applications of solar energy in daily life and technology.
• Discusses the importance of solar energy in terms of effective use of resources.
• Designs projects for economical use of resources.
• Discusses the ideas he has produced on how to benefit from solar energy in the future.
• Explains that fossil fuels are one of the limited and non-renewable energy sources.
• Explains the importance of renewable energy sources.
• Discusses the effects of using different types of fuels for heating purposes on humans and the environment.
• Classifies substances in terms of heat conduction.
• Recognizes the role of water in food in the proliferation of microorganisms.

Engineering Gains:

• Explains technologies for obtaining clean and sustainable energy by using natural resources such as water, wind and sun.
• Designs a product that can generate energy through natural resources using the Engineering Design Cycle.
• It offers the energy conversion product it has designed.
• Tries different design models for more efficient food drying.

Technology Gains:

• Can use a digital thermometer.
• Can use bacteria kit.
• Can use a digital scale.
• Can integrate DC Motor into the system.
• Can integrate the propeller into the system.
• Can integrate solar energy panel into the system.

Mathematics Gains:

• Measures temperature with a thermometer.
• Draws graphs by recording temperature values over time.
• Uses different geometric shapes in designs.
• Can make measurements using a digital scale.
• Can draw graphs from the data obtained.
• Can calculate percentages.

Artistic Gains:
• Prepares meals using the principles of sustainable gastronomy (the art of food).
• It uses local cultural motifs to make its designs aesthetic.

Entrepreneurial Gains
• It identifies social needs and produces innovative ideas to meet them.
• They use mass communication channels to promote the product they have developed.
• Expresses and discusses his ideas and findings clearly and consistently to the professional target audience using visual, written and verbal communication methods.

Nature of STEM / Career Gains:
• Assuming oneself as a team member in different roles in the project work
o4.Incorporates the best features of each item or solution by analyzing the similarities and differences between various design solutions for a new solution in order to meet success criteria.
• In project work, he assumes himself as a team member in different roles and successfully completes the work required by that role (understands the importance of interdisciplinary work).
• Becomes aware of basic science, technology and engineering disciplines and career opportunities in these fields.
• Researches the fields of study of different disciplines and gets to know current and interdisciplinary professions.

Green STEM Gains:
• Recommends environmentally friendly green science practices to minimize human impact on the environment to solve social needs or problems.

21st Century Skill Gains:
• Improves problem solving skills.
• Improves collaborative working skills (understands that many scientists and engineers work collaboratively in teams).
• His/her sensitivity to the environment and the world he/she lives in increases.

Nature of science (or scientific inquiry) Gains:
• Understands the importance of repeating experiments or measurements in experimental studies.
• Creates or revises scientific explanations based on valid and reliable data or evidence obtained from sources (including students' own experiments).
• Uses valid and reliable data or evidence from a variety of sources (including students' own research, experiments, models, peer evaluations, etc.) to support or evaluate the explanation or conclusion.
• Conducts a study and/or evaluates and/or revises the experimental design to find a solution to the problem and obtain data.

Relevant Green Deal Strategies:

GD3. Clean, Accessible and Safe Energy Supply

a) Applications for the Development of Clean, Domestic and Renewable Energy Resources, especially Wind, Solar and Geothermal, and their Integration with Existing Energy Systems, and thus Reducing Greenhouse Gas Emissions

GD4. Green and Sustainable Agriculture: Sustainable Agriculture from Field to Table

g) Innovative Practices for the Dissemination of Sustainable Agriculture Techniques from Field to Table

Theoretical Information:

Preserving fruits and vegetables by drying is a very old preservation method that has been used since ancient times. Since ancient times, fruits and vegetables, and later foods such as tarhana and tomato paste, have been dried in the sun. The purpose of drying is to remove moisture from the food. During drying, the moisture level in the food drops to a level that prevents the growth of microorganisms. Although the sun drying method is a natural and common method, it is a method that takes a long time and is subject to air pollution, microbial contamination and insects, etc. It brings along problems such as exposure to external influences. This situation has brought about the need for the development of more pleasant and hygienic industrial drying machines. Recently developed solar dryers have eliminated the existing negativities and increased energy efficiency by using solar energy as the best alternative energy source to fossil fuels instead of using electrical energy. In these systems, instead of solar energy affecting the product directly, the air circulating around the product is heated with solar energy. Although direct solar dryers are low in cost and easy to produce, temperature control is not possible in these dryers, so when vegetables and fruits are exposed to direct sunlight for a long time, their vitamin values decrease and color loss occurs. Air blow drying systems can provide faster and more homogeneous drying. In this type of dryers, a certain air speed is applied depending on the product and the product has a short drying time.

Keywords:

Solar energy, renewable energy, fossil fuel, sustainability, absorption, insulation, temperature, humidity level, hygiene

Learning Tools: Worksheets Digital Tools	**Tools and Materials to be Used:** Large cardboard boxes, fly screen, cardboard/cardboard, scissors, paper towel roll, aluminum foil, transparent tape, stretch film/transparent plastic/glass, black background paper, rock wool, glass wool, wood, ruler, digital thermometer, digital scale, bacteria kit, knife, plate, various fruits, various vegetables, paper tape, solar panel-mini motor-propeller set

Literature Resources for Students

Augustus Leon, M., Kumar, S. and Bhattacharya, S.C. (2002). A comprehensive procedure for performance evaluation of solar food dryers, *Renewable and Sustainable Energy Reviews*, 6, 367–393.

Güngör, A. ve Özbalta, N. (2019). Güneş enerjili kurutma teknolojileri ve uygulamalarda gelişmeler. *8. Güneş Enerjisi Sistemleri Sempozyumu ve Sergisi,* 8-9 Kasım 2019, Mersin.

Ekechukwu O.V. and Norton, B. (1999). Review of solar-energy drying systems II: an overview of solar drying technology, *Energy Conversion & Management,* 40, 615-655.

Erbay, B. ve Küçüköner, E. (2008). Gıda endüstrisinde kullanılan farklı kurutma sistemleri, *Türkiye 10. Gıda Kongresi,* 21-23 Mayıs 2008, Erzurum.

Sharma, A., Chen, C.R., Lan, N. V., (2009). Solar-energy drying systems: A review, *Renewable And Sustainable Energy Reviews*, 13, 1185-1210.

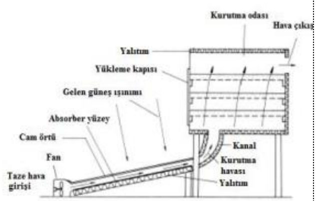
Literature Resources for Teachers

Augustus Leon, M., Kumar, S. & Bhattacharya, S.C. (2002). A comprehensive procedure for performance evaluation of solar food dryers, *Renewable and Sustainable Energy Reviews*, 6, 367–393.

Güngör, A. ve Özbalta, N. (2019). Güneş enerjili kurutma teknolojileri ve uygulamalarda gelişmeler. *8. Güneş Enerjisi Sistemleri Sempozyumu ve Sergisi,* 8-9 Kasım 2019, Mersin. Ekechukwu O.V. and Norton, B. (1999). Review of solar-energy drying systems II: an overview of solar drying technology, *Energy Conversion & Management,* 40, 615-655. Erbay, B. ve Küçüköner, E. (2008). Gıda endüstrisinde kullanılan farklı kurutma sistemleri, *Türkiye 10. Gıda Kongresi,* 21-23 Mayıs 2008, Erzurum. Sharma, A., Chen, C.R., Lan, N. V., (2009). Solar-energy drying systems: A review, *Renewable And Sustainable Energy Reviews*, 13, 1185-1210.	
Teaching Methods:	Problem-Based Learning, Inquiry-Research, Project-Based Learning, Design Thinking and Engineering Design, (Hands-on Science) Applied Learning, Technology-Assisted Learning

Green STEM Teaching Activity Scenario: Solar Food Dryer

Stage	**Time Required**	**Teacher Activity**	**Student Activity**
Defining the Problem	30 minutes	The problem should be included both in the worksheet to be distributed to the students and the problem should be presented to the students by visually projecting it. Students are enabled to read and analyze the problem situation and discuss it with their peers. Thus, the problem situation is diagnosed and defined as a group. At this stage, it is aimed for the students to understand the problem situation. For the activity, heterogeneous groups of students should be formed as much as possible. In study groups, the professions given in the worksheet should be shared and the duties and responsibilities of the student who undertakes each profession should be determined and written down.	Students read and analyze the problem situation presented in the worksheet and discuss it with their peers. In groups, they fully present the problem. Students share the professions given in the worksheet in line with their interests, and the duties and responsibilities for each student are determined and recorded in **Student Worksheet 1**.
Remembering and Researching	1 hour	In order to reveal their prior knowledge about the problem and possible solution(s), students are asked to write down what they know and their experiences within the framework of the following questions in the **Remembering What is Known and Experiences** section of **Student Worksheet 1.**	Information and experiences regarding the questions given regarding the problem situation are

		• What are renewable energy sources? • What are the effects of fossil fuels on humans and the environment? • What is the importance of solar energy? • Does the color of materials affect the amount of absorption of sunlight? How? • What methods are used to preserve food for a long time? • How can solar energy be used to preserve food for a long time? • Why can foods be stored longer when dried? Under the heading "**What Needs to be Researched**", students are encouraged to think about what questions they need to find answers to in order to find a solution to the problem. For example, "*What are environmentally friendly materials?, What should be taken into consideration when drying foods?, Can foods be dried at all temperatures?, "What are the moisture levels in dried fruits/vegetables?"* It is aimed for them to develop researchable questions such as: They are asked to record their questions in **Student Worksheet 1.** Afterwards, students are asked to research the answers to these questions and write their answers. They are warned to include the sources they use. 	recorded as a group in **Student Worksheet 1.** Researchable questions are put forward by thinking about which questions need to be answered in order to find a solution to the problem. Questions are recorded in **Student Worksheet 1**. The answers to these questions are researched and recorded. The sources used are also included.
		In the Solution Generation-Product Design phase, the features that the product that students are asked to design must have are given in **Student Worksheet 2** as design criteria.	Within the framework of the given design criteria, all ideas

Solution Generation-Product Design	1 hour	**Design Criteria:** • Food drying should be done with solar energy. • It should provide hygienic drying. • Factors affecting the negative change in the color of foods should be taken into account. • It should be produced with environmentally friendly materials. • It should be able to fit a tray with dimensions of 30*30 cm. • It must be aestheticized with local cultural motifs. • A creative recipe must be created using dried fruit/vegetable/tarhana/tomato paste. Students are given an explanation of the design criteria. Students are expected to put forward all the different ideas they think of for the problem by considering the design criteria and brainstorming. Students should be made aware that there may be more than one correct way to find a solution. They are asked to record all their ideas in **Student Worksheet 2.** Afterwards, students should be guided to choose the most appropriate one among the ideas and use it to develop a prototype. In order to improve decision-making skills, "Which of the ideas did you decide to use and why?" They should be made to think by asking questions. At this stage, students are expected to decide what kind of prototype they will make within the design criteria. They are also encouraged to identify the materials needed to implement the chosen idea. All materials required for the event should be prepared in advance. Students should be asked to describe the design of the product in detail and draw it with measurements like an engineer. Students are expected to design a food dryer like the one on the side (*it is only given as an example. There may be many different designs that meet the criteria*). The shape, visual appearance and materials used of the	considered as problem solutions are put forward and recorded in **Student Worksheet 2**. By discussing in groups, the most appropriate idea is selected. The materials required for the implementation of the selected idea are also determined. The design of the product is explained in detail and a drawing is made with measurements like an engineer.

		dryer may vary depending on the creativity of the students and their research.	
Prototyping and Testing	5 hours	In the **Prototyping and Testing** phase, students are guided to create a prototype of the product by implementing their plans and using appropriate materials. They are asked to test the resulting product using fruits/vegetables. In this process; -Students are asked how they can determine the amount of moisture lost in the fruits/vegetables they use to dry. (Students may suggest determining the initial mass of the fruit they are using and the amount of moisture removed by measuring the mass from time to time during drying. Or they may also suggest using a hygrometer.) - Students are directed to think about whether foods can be dried at all temperatures and to use the information they have researched in the previous section to determine what the appropriate ambient temperature should be for each fruit/vegetable for drying. Students should also be asked questions about how they can achieve this temperature while testing the product. -Students are required to use a period of 3-4 hours (or more if the conditions are suitable) for drying and to determine the amount and percentage of moisture removed from the fruits/vegetables they sliced and dried at certain time periods during this period and to draw graphs of the data they obtained (using **digital tool**) is requested. - Students are asked to investigate the moisture content of dried fruits/vegetables and determine approximately how long it will take for the fruit/vegetable to dry in the solar food dryer prototype. -At the end of the drying time, students are directed to determine the amount of microorganisms (bacteria) in the dried fruit/vegetable. -Students are also encouraged to obtain the same type of data on open drying in the sun and compare it with their other data to interpret the advantages and disadvantages of the two methods.	A prototype of the product is created by applying the drawing and using appropriate materials. The resulting product is tested using various fruits/vegetables. In this process; -A method is recommended to determine the amount of moisture lost in fruits/vegetables used for drying. -The research information in the previous section is used to determine what the appropriate ambient temperature should be for each fruit/vegetable for drying by considering whether foods can be dried at all temperatures. While testing the product, ideas are generated on how this temperature

			can be achieved. - The amount and percentage of moisture removed from the slicing and drying fruits/vegetables are determined at certain time periods throughout the entire sura. A graph of the obtained data is created (using a **digital tool**). - By investigating the moisture content of dried fruits/vegetables, it is determined approximately how long the fruit/vegetable used will dry in the solar food dryer prototype. -At the end of the drying time, the amount of microorganisms (bacteria) in the dried fruit/vegetable is measured. In addition, the same type of data is obtained regarding open drying under

			the sun and compared with other data, the advantages and disadvantages of the two methods are interpreted.
Product Introduction, Discussion and Evaluation	1 hour	For **Product Promotion, Discussion and Evaluation**, students are asked to prepare a poster using a **digital tool**, planning how they will promote their products and inform relevant people, and they are asked to record it in **Student Worksheet 2**. They are encouraged to include a recipe and visuals of a meal to be prepared from foods dried with the product using the principles of gastronomy (the art of food) in the poster. Afterwards, each group's product is evaluated using the evaluation rubric prepared in accordance with the design criteria and available in the worksheet, under the guidance of the teacher and with the participation of all groups. Depending on the evaluation, it is debatable how much the product solves the problem.	A poster is prepared by planning how the product will be promoted and how the relevant people will be informed. The poster also includes a recipe for a meal to be prepared using the principles of gastronomy (the art of cooking) from foods dried with the product. The product of each group is evaluated using the evaluation rubric in accordance with the design criteria, under the guidance of the teacher and with the participation of all groups. Based on the evaluation, the class discusses how well the product solves the problem. In addition, the advantages and

			disadvantages of different design products produced by the groups are discussed with the participation of the whole class.
Developing the Product	30 minutes	Students are asked to discuss among themselves the changes they plan to improve the product and record them in **Student Worksheet 2.**	In order to improve the product, changes that can be made to the product are planned by discussing it in a group and recorded in **Student Worksheet 2.**
Sharing What I Learned	30 minutes	Students are asked to share what they have learned by discussing it within the framework of the questions written below and record it in **Student Worksheet 3.** - Write down what you learned during the preparation and design phase of the solar food dryer. - Write down what you learned during the prototyping phase of the solar food dryer. - Write down what you learned during the testing phase of the solar food dryer. - Write down what you learned during the product introduction phase of the solar food dryer. - Write down what you learned during the product development phase of the solar food dryer. - Explain what would be the benefits of designing a product that is completely based on solar energy, provides environmentally friendly and sustainable cooking.	What is learned is answered and recorded by discussing it in groups within the framework of the questions given in **Student Worksheet 3.**