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GREEN STEM EDUCATION GUIDELINE FOR ACADEMIC STAFF - TEACHER'S EDUCATORS



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Green STEM education guideline for academic staff - teacher's educators



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Authors (in alphabetical order):

Assist. Prof. Dr. Damyana Grancharova (South-West University "Neofit Rilski"), Prof. Dr. Ivanka Stankova (South-West University "Neofit Rilski"), Assoc. Prof. Dr. Maya Chochkova (South-West University "Neofit Rilski"), Assoc. Prof. Dr. Mitko Stoev (South-West University "Neofit Rilski"), Assist. Prof. Dr. Petranka Petrova (South-West University "Neofit Rilski");

Prof. Dr. Eylem Bayır (University of Trakya), Prof. Dr. Şebnem Selen İşbilir (University of Trakya), Assoc. Prof. Dr. Hüsnüye Durmaz (University of Trakya), Assoc. Prof. Dr. Sertaç Arabacıoğlu (University of Trakya), Assist. Prof. Dr. Emrah Oğuzhan Dinçer (University of Trakya), Assist. Prof. Dr. Hasan Özyıldırım (University of Trakya),

Prof. dr. Vesna Ferk Savec (University of Ljubljana), Assoc. Prof. dr. Bostjan Genorio (University of Ljubljana), Assist. Prof. dr. Danijela Makovec Radovan (University of Ljubljana), Assist. Ema Meden (University of Ljubljana), Assist. Katarina Mlinarec (University of Ljubljana)



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THEORETICAL BACKGROUND



THEORETICAL BACKGROUND

1. Literature review

Attempting to advance sustainable thinking in practice by engaging networks of chemists and stakeholders to develop Education for Sustainable Development (ESD) are part of the 2030 Agenda framework, particularly the fourth Sustainable Development Goal (SDG) (United Nations Sustainable Development Knowledge Platform, 2015a), which in SDG4 – Quality Education aims to ensure inclusive, equitable, and quality education and promote lifelong learning opportunities for all (United Nations Sustainable Development Knowledge Platform, 2015b;). In relation to SDG 4 it was found that progress towards quality education was already slower than required before the pandemic, but COVID-19 has had devastating impacts on education in many countries (United Nations Sustainable Development Knowledge Platform, 2023). Based on SDG Summit in September 2023 an SDG Summit Acceleration and Accountability Platform was launched, which showcases the registered initiatives, actions, policies and commitments of Member States and stakeholders, aimed at accelerating progress towards the SDGs and delivering the breakthroughs we need to transform our world by 2030 (SDG Summit Acceleration and Accountability Platform, 2023). Several of the presented initiatives include SDG4, e.g. Sustainable Development Open Education Resource Platform (2023) aims to support inclusive knowledge sharing and innovation to accelerate progress across the entirety of the SDGs through open educational resources; Innovation to Transform Education Training (2023) aims to ensure the capacity of youth and students to become agents of change in transforming education in their specific national contexts through innovation; Eco-pedagogical Microforest (2023) aims to increase young people’s sustainable values through process, from co-design to co-realization, explores an easy to handle and fast growing Microforest to be planted within the size of a neighborhood, etc.

Green chemistry in general aims to promote environmentally friendly behaviors, a change that is essential for sustainable development. In integrating the Sustainable Development Goals (SDGs) into Green Chemistry Education (GCE), an interdisciplinary framework should be considered to examine how cognitive, social, and emotional factors interact to promote understanding of environmental issues and problems (Mammino, 2018) and that systems thinking can be used to connect green principles with SGDs (D’eon, & Silverman, 2023). Mitarlis, Azizah, & Yonata (2023) claim that chemistry education should support SDGs, especially the SDG12 - Responsible Consumption and Production and/or SDG 13 - Climate Action, thereby the principles of green chemistry can be implemented in chemistry learning



in various activities such as: waste prevention, use the safe solvent, energy efficiency, and creating safe and secure conditions for learning both in the classroom and laboratory.

Various approaches are described in the literature, on how to implement Green Chemistry Education in pedagogical process, e.g.:

- integrating Green Chemistry into traditional chemistry teaching (Abraham, Stachow & Du, 2020; Ali, Harris & Lalonde, 2020; Armstrong, Burnham & Warminski, 2017; Bachofer & Lingwood, 2019; Bailey et al., 2015),
- introducing of Green Chemistry into the curriculum (Armstrong et al., 2019; Aubrecht et al., 2019; Braun et al., 2006; Haack et al., 2005, Karpudewan, Ismail & Mohamed, 2009),
- integrating Green Chemistry into textbooks, and other learning materials (Ahluwalia, 2012; Cann, 2009; Johnson et al., 2020; McMurry, 2012; Smith, 2011),
- developing of lectures, courses, and MOOCs (Massive Open Online Courses) in Green Chemistry (Gross, 2013; Mammino, 2018; Haley et al., 2018; Loste et al., 2020; Summerton, Hurst & Clark, 2018),
- use of various types of metrics for determining the “greenness” of a chemical reactions (Cheney et al., 2008; Cosio et al., 2020; Ribeiro & Machado, 2011; Gómez-Biagi & Dicks, 2015; Nigam et al., 2016),
- use of various types of experimental work related to the of Green Chemistry topics (Karpudewan, Ismail & Roth, 2012; Yadav, Mande, & Ghalsasi, 2012; Sharma, Gulati & Mehta, 2012; Abraham, Stachow & Du, 2020; Silverman & Hudson, 2020),
- supporting the development of students’ systems thinking through Green Chemistry practice (Dicks et al., 2019; Aubrecht et al., 2019; Mahaffy et al., 2018; Marcelino, Sjöström & Marques, 2019; Miller et al., 2019),
- implementing of Green Chemistry to boost sustainable development using synergies with other environmental strategies such as Environmental Management System, Life-Cycle Analysis, Circular Economy and Industrial Ecology (Loste & Roldán, 2019; Loste et al., 2019; Mooney, Vreugdenhil & Shetranjiwalla, 2020; Reeb, Lucia & Venditti, 2013; Davidson et al., 2021),
- facilitating students’ active learning in the context of Green Chemistry, e.g. project-based learning, problem-based learning, inquiry-based learning (Salgado-Chavarría & Palacios-Alquisira, 2021; Paristiowati et al., 2022; Liu et al., 2023).

In the following part of the literature review, we focus primarily on the role of experimental work and students’ active learning in GCE, which we consider particularly important for our project.



In line with the increased number of publications in the field of teaching green chemistry for sustainability (Marques et al., 2020), from 2011 onwards there was a significant wave of publications of scientific papers on the implementation of green chemistry in experimental laboratory work, especially in the form of experience reports that point to many examples of good teaching practice (Ferk Savec & Mlinarec, 2021). The results show that some of the principles of green chemistry are predominantly used in the optimization of experimental work, e.g., substitution of solvents and other auxiliary materials (Green Chemistry Principle 5), waste prevention (Green Chemistry Principle 1), and use of catalysts (Green Chemistry Principle 9) (Ferk Savec & Mlinarec, 2021). Although in most cases not all principles were included, it is important to keep in mind that even the application of a single green chemistry principle can make a big difference. Therefore, the number of green chemistry principles included in experimental work should not be understood as "all or nothing" but rather as striving for "the more, the better." It is important to develop students' green chemistry skills by asking them simple questions such as e.g. "What is green about the experiment?"; "What is not green?"; and "How could the experiment be optimized to be greener?" (Andraos & Dicks, 2012; Płotka-Wasyłka et al., 2018).

Andraos & Dicks (2012) suggest that updating science education with laboratory experimental work optimized from green chemistry perspectives provides a safer approach to teaching chemistry topics and ensures a safer learning environment by minimizing exposure to potentially hazardous chemicals and reducing the generated waste. The importance of teaching chemical safety by recognizing that there is considerable overlap between reflection on the 12 green Chemistry Principles and the paradigm RAMP (recognize hazards, assess the risks of hazards, minimize the risks of hazards, and prepare for emergencies) has been also pointed out (Aubrecht et al., 2019; Goode, Wissinger & Wood-Black, 2021).

Ferk Savec & Mlinarec (2021) found that "step-by-step" laboratory instruction (traditional/expository) is most used in laboratory environments within green chemistry education, which is consistent with findings on the use of laboratory work in chemical education of other topics (Johnstone & Al-Shuaili, 2001). It is followed by "inquiry-based learning" (IBL), which is the most widespread in the laboratory in the category of active learning in the field of green chemistry and covers a broad number of subject areas (Summerton, Hurst, & Clark, 2018; Ferk Savec & Mlinarec, 2021).

A range of studies has explored the use of project-based and problem-based learning in the context of green chemistry. Salgado-Chavarría & Palacios-Alquisira (2021) applied a problem-based approach to the study of polycondensation reactions, with a focus on the Twelve Principles of Green Chemistry. Kennedy (2016) designed a dynamic undergraduate



green chemistry course based on project-based learning that required students to create their own green chemistry educational materials. Nagarajan & Overton (2019) highlighted the potential of project- and problem-based learning in promoting systems thinking, particularly in the context of global challenges related to the environment, water, public health, and energy. Ablin (2018) designed a course, where students investigated a given industrial business/company and were challenged to propose major changes to a synthesis, process, or procedure by implementing one or more of the 12 principles of green chemistry during their project-based learning. Shetranjiwalla & Hu (2023) present a novel project-based learning experience where students designed their own, multistep, green chemistry experiment using the virtual platform. The designed experiments capitalized on the safe, energy, and resource no intensive nature of the virtual platform to inspect chemical variations that would traditionally be hazardous or inaccessible within a physical undergraduate laboratory. These studies point out the value of project-based learning in green chemistry education, particularly in fostering a deeper understanding of the principles and their application in real-world contexts.

2. Selection and development of innovative methodology for presenting the learning content on each of the topics.

2.1. Methodology for presenting the learning content in the course for students

The course for students emphasizes students' experimental work, encouraging students to build, test, and analyze green technology systems using students' project-based learning. This approach fosters a practical understanding of the technologies' real-world applications and stimulates critical thinking about their role in a sustainable energy future.

Green technologies, often referred to as sustainable or clean technologies, represent a diverse array of innovations aimed at mitigating environmental impact and promoting ecological sustainability. These technologies leverage advancements in science, engineering, and design to tackle urgent environmental challenges such as climate change, resource depletion, and pollution.

The course for students will cover the following technologies:

Hydrogen Fuel Cells: Students will gain insight into this cutting-edge technology crucial for future sustainable energy. Fuel cells, electrochemical devices converting chemical energy into electricity, are explored with a focus on principles, types (e.g., proton-exchange membrane, solid oxide), efficiency, environmental benefits, and applications in transportation, power generation, and electronics. Challenges like cost and hydrogen production methods are discussed.



Electrolyzers: Students will learn about water electrolyzers using electrolysis to split water into hydrogen and oxygen. Fundamental concepts, types (alkaline, proton exchange membrane, solid oxide), efficiency, scalability, and economic aspects of water electrolysis are covered. Students engage with emerging research in materials science and catalyst design, gaining a holistic understanding of water electrolysis.

Lithium-ion (Li-ion) Batteries: The curriculum provides a comprehensive understanding of Li-ion batteries, covering electrochemical processes, ion migration, charge and discharge cycles, materials in electrodes, nanotechnology, safety considerations, and diverse applications. This knowledge equips students to contribute to the development and improvement of Li-ion battery technologies.

Sodium-ion (Na-ion) Batteries: Students gain a deep understanding of Na-ion batteries, exploring fundamental principles, electrochemical reactions, electrode and electrolyte materials, design considerations, advantages, challenges, and the latest research advancements. This knowledge positions students to comprehend the pivotal role of Na-ion batteries in shaping future energy storage technologies.

Beyond Li-ion Batteries: Students explore emerging technologies like solid-state batteries, novel materials (e.g., graphene), and next-generation battery chemistries (e.g., lithium-sulfur, lithium-air, redox flow, etc.) promising higher energy density, enhanced safety, and longer lifespan. The course aims to instill an understanding of these technologies surpassing current limitations and paving the way for more sustainable energy storage solutions.

Electrochemical (Micro) Reactors: Students gain insights into the design and fabrication of electrochemical (micro) reactors, exploring materials, manufacturing techniques, and integration methods. The course addresses applications ranging from energy conversion and storage to chemical synthesis and sensing.

Photovoltaics: Students learn to harness solar energy using PV technology. The curriculum covers basics, including sunlight conversion into electricity, the photovoltaic effect, solar cell design, materials (e.g., silicon), and various technologies. Factors affecting solar cell efficiency, system components like inverters and batteries, and skills for solar PV system design and installation are discussed.

Wind Turbines: Students understand the technology, principles, and role of wind turbines in renewable energy. The curriculum covers aerodynamics, design considerations, various turbine types, and integration into the energy grid, including storage and challenges with changing wind speeds.



2.2. Methodology for presenting the learning content in the course for teachers

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.

3. Development of summaries of the topics and courses for promotional purposes

3.1. Summary of the courses for students

The course at the University of Ljubljana for prospective science teachers entitled Sustainable Technologies in Science Education covers the actual topics Hydrogen Fuel Cells, Electrolyzers, Lithium-ion Batteries, Sodium-ion Batteries, Beyond Li-ion Batteries, Electrochemical (Micro) Reactors, Photovoltaics and Wind Turbines. The students'



knowledge acquired in the lectures is supplemented by practical experience in project-based learning.

3.2. Summary of the courses for teachers

This Green STEM teacher professional development model incorporates innovative learning and teaching tools specifically designed for natural sciences and sustainability. The professional development model consists of two stages. The first eight modules of the program address the theoretical foundations of the GREEN STEM approach prepared for teachers and the understanding to be imparted. The last seven modules include practical and interactive GREEN STEM in-class practices, serving as a guiding framework for teachers in the instructional process.

In the theoretical section, content that teachers need to acquire related to the Green STEM model includes an introductory module establishing the philosophical and theoretical foundations of green STEM education, insights from GREEN STEM research regarding future professions, the transformation of learning environments and research areas in the Green STEM context, and content on evaluating GREEN STEM learning and teaching processes and instructional practices. In addition, examples of applied and interactive activities consist of activities and teaching materials such as " Atmospheric Water Harvesting" " Renewable energy sources: Salt Tower & 24/7 (uninterrupted) use of Solar Energy " "Green Agriculture and Industrial Products: Pectins from Sunflower," and "Design-Based Green STEM Practices: Sun Dryer."

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COURSE SYLLABUS



COURSE SYLLABUS

Course Syllabus for Green STEM Training Program for Students: Innovative course in Green STEM for student training

УЧЕБНА ПРОГРАМА

ДИСЦИПЛИНА/ COURSE SYLLABUS						
Наименование на курса:	Иновативни STEM методи в обучението по природни науки					
Course title:	Innovative course in GREEN STEM for student training					
Образователно-квалификационна степен: Study programme and level	Професионално направление Study field	Година Academic year	Семестър Semester			
ОКС “бакалавър“	1.3.	2024	2			
Educational chemistry, Bachelor degree	1.3.	2024	2 nd			
Вид на дисциплината / Course type					Избираема/ Elective	
Код на дисциплината/ University course code:						
Лекции Lectures	Семинари/Упражнения Seminar/ Exercise	Tutorial work	Други форми на обучение	Извън аудиторна заетост Individ. work	Кредити ECTS	
30	15			45	3	
Лектор / Lecturer:		Assist. Prof. Dr. Damyana Grancharova				
Език / Languages:	Лекции / Lectures:	Английски ез. / English				
	Упражнения / Tutorial:	Английски ез. / English				
Предварителни изисквания:			Prerequisites:			
Необходими са основни познания по методика на обучението по химия и по химия и човекът и природата за успешното усвояване на учебния материал.			Basic familiarity with the teaching methodologies in chemistry and the interconnectedness of humanity and nature will enhance the successful comprehension of course material.			



<p>Цели и задачи на учебната програма:</p> <p>Курсът по „ЗЕЛЕН STEM“ прилага иновативни подходи на преподаване в областта на природните науки и формиране на компетенции за устойчиво развитие.</p> <p>Учебната програма е структурирана в следните модули: „STEM - подходи в обучението по природни науки“ и „Съвременни технологии в ЗЕЛЕН STEM“. Обхванатите теми включват същността на преподаване по природни науки, устойчиви методологии за наблюдение, моделиране на екологични системи, експерименти, интегриращи разширена реалност, и други далновидни методи.</p> <p>Основни цели:</p> <ol style="list-style-type: none"> 1. Проучване на съвременните подходи в преподаването на природните науки: Студентите ще придобият представа за съвременните методологии на преподаване, специално предназначени за образованието по природни науки. 2. Придобиване на умения за иновативни подходи на преподаване: придобиване на фундаментални познания за нови и иновативни техники на преподаване, свързани със ЗЕЛЕН STEM. 3. Анализ на различни иновативни подходи: Изследване и оценяване на ЗЕЛЕНИ STEM иновативни педагогически методи, които са от съществено значение за разбирането и ангажирането с природните науки. 	<p>Key Objectives of Syllabus:</p> <p>This cutting-edge course in Green STEM explores innovative teaching approaches tailored for natural sciences and sustainability. The syllabus is structured into the following modules: "STEM Teaching Methods for Natural Sciences" and "Advanced Techniques in Green STEM Education". Topics covered include the essence of natural science, sustainable observation methodologies, modelling for ecological systems, experiments integrating augmented reality, and other forward-thinking methods.</p> <p>Key Objectives:</p> <ol style="list-style-type: none"> 1. Exploration of Modern Teaching Approaches in Natural Sciences: Students will gain insight into contemporary teaching methodologies specifically designed for natural science education. 2. Establishing Proficiency in Innovative Teaching Approaches: Building foundational knowledge of new and inventive teaching techniques relevant to Green STEM. 3. Analysis of Diverse Innovative Approaches: Examining and assessing various green STEM innovative pedagogical methods essential for comprehending and engaging with natural sciences.
<p>Цели и компетентности:</p> <p>Целевите студентите ще могат да: Придобият фундаментални педагогически знания, като използват съвременни инструменти и методологии за обучение.</p> <p>С цел да се улесни по-задълбоченото разбиране на концепциите на Green STEM, ще се насърчи активното участие на студентите.</p> <p>Очаквани резултати:</p> <ul style="list-style-type: none"> ● Придобиване на знания: Очаква се студентите да придобият фундаментални знания, които да им позволят да се допълнително специализират в зелените STEM дисциплини. ● Задълбочаване на методологиите на преподаване: Курсът има за цел да разшири и задълбочи разбирането на съвременните методи на преподаване, конкретно приложени към природните науки. 	<p>Objectives and competences:</p> <p><i>Objectives</i> students will be able to: Earn fundamental pedagogical knowledge while utilizing modern teaching tools and methodologies. Active student participation is encouraged to facilitate a deeper understanding of Green STEM concepts.</p> <p>Expected Outcomes:</p> <ul style="list-style-type: none"> ● Knowledge Acquisition: Students are expected to gain foundational knowledge, enabling them to further specialize in Green STEM disciplines. ● Expansion of Teaching Methodologies: The course aims to broaden and deepen understanding of contemporary teaching methods specifically applicable to natural sciences.
<p>Очаквани резултати от обучението:</p>	<p>Intended learning outcomes:</p>



<p>Студентите ще придобият знания за ефективните методологии за преподаване, насочени към природните науки в сферата на Green STEM, насърчавайки научната грамотност във връзката човек-природа.</p> <p>Студентите ще се запознаят със съвременните принципи и методологии, които са жизненоважни за зеленото STEM образование, наблюдайки на иновативни подходи и устойчивост в областта на околната среда и природните науки.</p>	<p>Students learn about effective teaching methodologies specifically tailored for natural sciences within the realm of Green STEM, fostering scientific literacy in the human-nature relationship.</p> <p>To familiarize students with advanced principles and methodologies vital for Green STEM education, emphasizing innovative approaches and sustainability in environmental and natural sciences.</p>
<p>Методи на преподаване:</p>	<p>Learning and teaching methods:</p>
<p>Лекции, семинарни/ упражнения.</p>	<p>Lectures, seminars/ labwork.</p>

Оценяване:	Дял (%) / Weight (%)	Assessment:
Текущи контроли (2 теста)	2 x 10	Midterm exams (2 tests)
Презентация на проекта	20	Project presentation
Оценка от упражненията/семинарите	20	Exercises/ seminars assessment
Общо	60	Total

CONTENT OF THE EDUCATIONAL PROGRAM	
<p>The Course Program “Innovative course in Green STEM for student training” includes lectures and seminar exercises.</p>	
<p>A) LECTURES</p>	
<p><i>The lecture course is structured into 2 modules with a total duration of 30 study hours.</i></p>	
<p>Module A1:</p>	
<p>STEM TEACHING METHODS FOR NATURAL SCIENCES IN GREEN STEM</p>	<p>A1.1.</p>
<p>TEACHING METHODS FOR GREEN STEM</p>	
<p>Understanding the essence and characteristics of the concept of "teaching method" in the context of Green STEM. Methodological approaches specific to natural sciences. Classification of teaching methods. Types of competencies and scientific literacy within Green STEM. Teaching environmental sciences and fostering scientific literacy in Green STEM.</p>	
<p>5 hours</p>	
<p>A1.2. TEACHING METHODS IN NATURAL SCIENCES FOR GREEN STEM</p>	
<p>Exploring elements and structures of teaching methods for natural sciences within Green STEM. Various types and classifications of methods applicable to natural sciences. Indirect investigation methods relevant to Green STEM. Modeling methods for sustainability and environmental sciences within Green STEM.</p>	
<p>4 hours</p>	
<p>Expected Results. Students will acquire knowledge about teaching methods in natural sciences within Green STEM, grasp the essence of science in an environmental context, and develop skills in scientific research related to sustainability and the natural world.</p>	
<p>References: <i>Primary:</i> 1, 2, 3, 4, 5, 6, 7,8,9,10,11 <i>Supplementary:</i> 1, 2, 3, 4, 5, 6</p>	
<p>Midterm exam №1</p>	<p>1 hour</p>



Module A2:

ADVANCED TECHNIQUES IN GREEN STEM EDUCATION A2.1. OBSERVATION IN GREEN STEM NATURAL SCIENCES

Understanding observation and its application in teaching natural sciences within the context of Green STEM. Types of observation: spontaneous, independent, descriptive, systematic, teacher-guided, focusing on sustainability and environmental implications within Green STEM.

2 hours

A2.2. EXPERIMENTATION AND AUGMENTED REALITY IN GREEN STEM EDUCATION

Utilizing augmented reality in experimentation and teaching for environmental sciences within Green STEM. Shifting virtual data (audio-visual and multimedia content) for environmental learning. Various experiment types focusing on sustainability within Green STEM.

2 hours

A2.3. GREEN STEM LABORATORY, PRACTICAL WORK, AND VIRTUAL ENVIRONMENTS

Implementing internet simulations, demonstrations, and virtual laboratory experiments specifically tailored for environmental sciences within Green STEM. Exploring the potential of virtual reality in teaching about the human-nature relationship, emphasizing sustainability and environmental literacy in Green STEM.

2 hours

A2.4. MODELLING METHODOLOGY FOR SUSTAINABILITY EDUCATION IN GREEN STEM

Exploration of different types of models and their application in sustainability education within Green STEM. Utilizing the research approach to study content related to sustainability and the environment, enhancing scientific literacy within Green STEM.

2 hours

A2.5. PRACTICAL ACTIVITY METHODS FOR GREEN STEM EDUCATION

Implementing situational methods (case studies) and research-oriented approaches in teaching about the human-nature relationship within Green STEM. Application of research approaches for environmental scientific literacy within Green STEM.

2 hours

A2.6. COMMUNICATION METHODS IN NATURAL SCIENCES WITHIN GREEN STEM

Dialogue (heuristic dialogue), narrative, explanation, and lecture strategies focusing on Green STEM contexts. Developing effective presentations aligned with environmental sciences within Green STEM.

2 hours

A2.7. GREEN STEM TEXTUAL ANALYSIS AND APPLICATION

Developing skills to work with diverse sources such as educational, reference, scientific-popular literature, internet articles, etc., specifically emphasizing environmental challenges and sustainability within Green STEM. Problem-based presentation of environmental science material within Green STEM contexts.

2 hours

A2.8. RESEARCH-BASED LEARNING IN SUSTAINABILITY EDUCATION FOR GREEN STEM

Active learning, problem-based learning, and the implementation of research-based methods ("learning through research") specifically designed for Green STEM education, emphasizing sustainability and environmental research.

2 hours

A2.9. GREEN SCIENCE INTO STEM SYLLABUS INTER-DISCIPLINARY APPROACHES TO GREEN STEM INTEGRATION

Brainstorming sessions focusing on sustainability and environmental challenges within Green STEM contexts. The connection of Green STEM with the public engagement and the environments industry.

2 hours

A2.10. RESULTS ANALYSIS AND MODELING FOR SUSTAINABILITY IN GREEN STEM

Building models, conducting simulations, and presenting scientific reports based on sustainability and environmental learning within the context of Green STEM education.

1 hour

Midterm exam №2

1 hour

B) EXERCISES/ SEMINARS/ Conducting green experiments and projects

1. Exploring *renewable energy sources*, sustainable energy technologies, and life cycle impact assessment through advanced computational tools within the realm of Green STEM.

1 hour



2. Analyzing corporate sustainability practices and their integration with social *responsibility in the context of Green STEM initiatives*.
1 hour
3. Understanding *Wind Power systems* and their integration into the methodologies of Green STEM for sustainable energy generation.
1 hour
4. Evaluating Concentrated *Solar Power* within the spectrum of Green STEM sustainability practices.
1 hour
5. Evaluating Concentrated *Solar Photovoltaic technologies* within the spectrum of Green STEM sustainability practices.
1 hour
6. Harnessing the potential and applications of *Bioenergy* within the framework of Green STEM principles.
1 hour
7. Harnessing the potential and applications of *Hydropower* within the framework of Green STEM principles.
1 hour
8. Delving into *Geothermal Energy* solutions through the lens of Green STEM sustainability practices.
1 hour
9. Exploring innovative *Energy Storage methods* in alignment with Green STEM sustainability frameworks.
1 hour
10. Understanding the role and implications of *Nuclear Power* within the purview of Green STEM practices.
1 hour
11. Investigating the *environmental pollution* harvesting technologies and their alignment with Green STEM sustainability frameworks.
1 hour
12. Exploring *biodiversity* and their relevance within the spectrum of Green STEM initiatives.
1 hour
13. Understanding the implications of Green STEM among teachers and joint conduct of lesson units, hours of the full-day *organization of the study day, extracurricular activities, as well as activities in partnership with external organizations* (museums, libraries, observatories, research centers, etc.).
1 hour
14. Researching sustainable methods to optimize *transport infrastructure and reduce carbon emissions and the greenhouse effect* and its integration with Green STEM principles for sustainable practices.
1 hour
15. Exploring the implementation of *organic farming methods that use natural techniques for soil nutrition and pest control* within the framework of Green STEM practices.
1 hour

СЪДЪРЖАНИЕ НА УЧЕБНАТА ПРОГРАМА

Програмата на курса „ Иновативни STEM методи в обучението по природни науки “ включва лекции и семинарни упражнения.

А) ЛЕКЦИИ

Лекционният курс е структуриран в 2 модула с обща продължителност от 30 учебни часа.

Модул А1:

STEM МЕТОДИ НА ОБУЧЕНИЕ ПО ПРИРОДНИ НАУКИ В ЗЕЛЕН STEM

А 1.1. МЕТОДИКА НА ОБУЧЕНИЕ ЗА ЗЕЛЕН STEM

Разбиране на същността и характеристиките на понятието „метод на обучение“ в контекста на ЗЕЛЕН STEM. Специфични за природните науки методологични подходи. Класификация на методите на обучение. Видове компетентности и природонаучна грамотност в рамките на ЗЕЛЕН STEM. Преподаване на науки за околната среда и насърчаване на природонаучната грамотност в ЗЕЛЕН STEM.

5 часа



A1.2. МЕТОДИКА НА ОБУЧЕНИЕ ПО ПРИРОДНИ НАУКИ ЗА ЗЕЛЕН STEM

Проучване на елементи и структури на методите на обучение по природни науки в сферата на ЗЕЛЕН STEM. Различни видове и класификации на методи, приложими в природните науки. Косвени методи за изследване, свързани със ЗЕЛЕН STEM. Методи за моделиране за устойчиво развитие за околната среда в рамките на ЗЕЛЕН STEM.

4 часа

Очаквани резултати. Студентите ще придобият знания за методите на преподаване по природните науки в рамките на ЗЕЛЕН STEM, ще разберат същността на науката в контекста на околната среда и ще развият умения в научните изследвания, свързани с устойчивостта и околната среда.

Литература: *Основна:* 1, 2, 3, 4, 5, 6, 7,8,9,10,11

Допълнителна: 1, 2, 3, 4, 5, 6

Текущ контрол №1

1 час

Модул А2:

СЪВРЕМЕННИ ТЕХНИКИ В ОБУЧЕНИЕТО ПО ЗЕЛЕН STEM

A2.1. НАБЛЮДЕНИЕ ПО ПРИРОДНИ НАУКИ В РАМКИТЕ НА ЗЕЛЕН STEM

Разбиране на наблюдението и приложението му в преподаването по природни науки в контекста на ЗЕЛЕН STEM. Видове наблюдение: спонтанно, независимо, описателно, систематично, ръководено от учителя, фокусирано върху устойчивостта и екологичните последици в рамките на ЗЕЛЕН STEM.

2 часа

A2.2. ЕКСПЕРИМЕНТ И ДОПЪЛНЕНА РЕАЛНОСТ В ОБУЧЕНИЕТО ЗА ЗЕЛЕН STEM

Използване на разширена реалност в експеримента и преподаването на науки за околната среда в рамките на ЗЕЛЕН STEM. Прехвърляне на виртуални данни (аудио-визуално и мултимедийно съдържание) за екологично обучение. Различни видове експерименти, фокусирани върху устойчивостта в рамките на ЗЕЛЕН STEM.

2 часа

A2.3. ЛАБОРАТОРИЯ ЗА ЗЕЛЕН STEM, ПРАКТИЧЕСКА РАБОТА И ВИРТУАЛНА СРЕДА

Прилагане на интернет симулации, демонстрации и виртуални лабораторни експерименти, специално пригодени за екологични науки в рамките на ЗЕЛЕН STEM. Проучване на потенциала на виртуалната реалност в преподаването на връзката човек-природа, наблягайки на устойчивостта и екологичната грамотност в ЗЕЛЕН STEM.

2 часа

A2.4. МЕТОДОЛОГИЯ ЗА МОДЕЛИРАНЕ НА ОБУЧЕНИЕ ПО УСТОЙЧИВО РАЗВИТИЕ В ЗЕЛЕН STEM

Проучване на различни видове модели и тяхното приложение в обучението по устойчиво развитие в рамките на ЗЕЛЕН STEM. Използване на изследователския подход за изучаване на съдържанието, свързано с устойчивостта и околната среда, повишаване на научната грамотност в рамките на ЗЕЛЕН STEM.

2 часа

A2.5. МЕТОДИ ЗА ПРАКТИЧЕСКА АКТИВНОСТ В ОБУЧЕНИЕТО ПО ЗЕЛЕН STEM

Прилагане на ситуационни методи (казуси) и изследователски ориентирани подходи в преподаването на връзката човек-природа в рамките на ЗЕЛЕН STEM. Приложение на изследователски подходи за екологична научна грамотност в рамките на ЗЕЛЕН STEM.

2 часа

A2.6. КОМУНИКАЦИОННИ МЕТОДИ В ПРИРОДНИТЕ НАУКИ В РАМКИТЕ НА ЗЕЛЕН STEM

Диалог (евристичен диалог), разказ, обяснение и стратегии за лекции, фокусирани върху контекста на ЗЕЛЕН STEM. Разработване на актуални презентации, съобразени с науките за околната среда в рамките на ЗЕЛЕН STEM

2 часа

A2.7. ТЕКСТОВ АНАЛИЗ И ПРИЛОЖЕНИЕ НА ЗЕЛЕН STEM

Развиване на умения при работа с разнообразни източници като образователна, справочна, научно-популярна литература, интернет статии и др., като специално се наблегне на екологичните предизвикателства и устойчивостта в рамките на ЗЕЛЕН STEM. Проблемно-базирано представяне на екологичен научен материал в контекста на ЗЕЛЕН STEM.

2 часа

A2.8. НАУЧНО - БАЗИРАНО ОБУЧЕНИЕ И УСТОЙЧИВОСТ В РАМКИТЕ НА ЗЕЛЕН STEM



Активно учене, проблемно - базирано обучение и прилагане на научно-базирани методи („учене чрез изследване“), специално предназначени при обучението ЗЕЛЕН STEM, наблягайки на устойчивостта и екологичните изследвания.

2 часа

A2.9. ЗЕЛЕНАТА НАУКА В УЧЕБНАТА ПРОГРАМА ЗА STEM ИНТЕРДИСЦИПЛИНАРНИ ПОДХОДИ

Brainstorming, фокусиран върху устойчивостта и екологичните предизвикателства в контекста на ЗЕЛЕН STEM. Връзката на ЗЕЛЕН STEM с обществената ангажираност и околната среда.

2 часа

A2.10. АНАЛИЗ НА РЕЗУЛТАТИТЕ И МОДЕЛИРАНЕ НА УСТОЙЧИВОСТ ПРИ ЗЕЛЕН STEM

Изграждане на модели, провеждане на симулации и представяне на научни доклади, базирани на устойчивост и екологично обучение в контекста на ЗЕЛЕН STEM.

1 час

Текущ контрол №2

1 час

Б) УПРАЖНЕНИЯ/ СЕМИНАРИ/ Провеждане на зелени експерименти и изготвяне на проекти

1. Проучване на възобновяеми енергийни източници, устойчиви енергийни технологии и оценка на въздействието върху жизнения цикъл чрез усъвършенствани изчислителни инструменти в сферата на ЗЕЛЕН STEM.

1 час

2. Анализиране на практики и тяхното интегриране в контекста на ЗЕЛЕН STEM.

1 час

3. Системи за вятърна енергия и тяхното интегриране в методологиите на ЗЕЛЕН STEM за генериране на устойчива енергия.

1 час

4. Оценка на концентрираната слънчева енергия в рамките на спектъра на ЗЕЛЕН STEM практики за устойчивост.

1 час

5. Оценка на концентрирани слънчеви фотоволтаични технологии в рамките на спектъра на ЗЕЛЕН STEM устойчиви практики.

1 час

6. Използване на потенциала и приложенията на биоенергията в рамките на принципите на ЗЕЛЕН STEM.

1 час

7. Използване на потенциала и приложенията на хидроенергията в рамките на принципите на ЗЕЛЕН STEM.

1 час

8. Вникване в принципите на геотермалната енергия през призмата на практиките за устойчивост на ЗЕЛЕН STEM.

1 час

9. Проучване на иновативни методи за съхранение на енергията в съответствие със ЗЕЛЕН STEM.

1 час

10. Разбиране на ролята и последиците от ядрената енергия в сферата на ЗЕЛЕН STEM практики.

1 час

11. Проучване на технологии за пречистване на околната среда от замърсяване и привеждане в съответствие.

1 час

12. Изследване на биоразнообразието и тяхното значение в сферата на ЗЕЛЕН STEM инициативи.

1 час

13. Изследване на последиците от ЗЕЛЕН STEM сред учителите и съвместно провеждане на часове от организацията на учебния ден, извънкласни дейности, както и дейности в партньорство с външни организации (музеи, библиотеки, обсерватории, изследователски центрове и т.н.).

1 час

14. Изследване на устойчивите методи за оптимизиране на транспортната инфраструктура и намаляване на въглеродните емисии и парниковия ефект, и интегрирането им в принципите на ЗЕЛЕН STEM за устойчиви практики.

1 час



15. Проучване на методите на биологичното земеделие, които използват естествени източници за подхранване на почвата и контрол на вредителите в рамките на ЗЕЛЕН STEM практики.

1 час

Използвана литература / Lecturer's references:

Primary:

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Additional literature:

- AlGerafi, M. A. M., Zhou, Y., Oubibi, M., & Wijaya, T. T. (2023). Unlocking the Potential: A Comprehensive Evaluation of Augmented Reality and Virtual Reality in Education. *Electronics*, 12(18), 3953. <https://doi.org/10.3390/electronics12183953>
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GREEN STEM TRAINING PROGRAM FOR TEACHERS

Program Overview

This Green STEM teacher professional development model incorporates innovative learning and teaching tools specifically designed for natural sciences and sustainability. The professional development model consists of two stages. The first eight modules of the program address the theoretical foundations of the GREEN STEM approach prepared for teachers and the understanding to be imparted. The last seven modules include practical and interactive GREEN STEM in-class practices, serving as a guiding framework for teachers in the instructional process.

In the theoretical section, content that teachers need to acquire related to the Green STEM model includes an introductory module establishing the philosophical and theoretical foundations of green STEM education, insights from GREEN STEM research regarding future professions, the transformation of learning environments and research areas in the Green STEM context, and content on evaluating GREEN STEM learning and teaching processes and instructional practices. In addition, examples of applied and interactive activities consist of activities and teaching materials such as " Atmospheric Water Harvesting " Renewable energy sources: Salt Tower & 24/7 (uninterrupted) use of Solar Energy " "Green Agriculture and Industrial Products: Pectins from Sunflower," and "Design-Based Green STEM Practices: Sun Dryer."

Program Duration

A minimum of 20 hours (over a defined period)

Key Objectives:

- ✓ Creating awareness and contextualization regarding the concepts of Green Science and Green STEM, emphasizing their relevance in everyday life applications and the importance of Green STEM education.
- ✓ Exploring Innovative Teaching Approaches in the Green STEM Model: Providing in-depth knowledge and understanding to educators about contemporary teaching approaches specifically designed for the Green STEM framework.
- ✓ Building Expertise in Innovative Teaching Approaches: Developing knowledge and understanding of new and creative teaching techniques related to Green STEM and transferring them to learning and teaching environments.
- ✓ Sharing and Implementing Diverse Innovative Examples: Examining and evaluating various exemplary practices and innovative pedagogical content that are fundamental for gaining understanding and engagement in Green STEM.



MODUL A.

Theoretical Framework of Green Science & STEM

TOPIC A.1: Introduction to Green Science & STEM

Duration: 2 hours

Outcomes:

- Global perspectives on Green Science
- The importance of Green STEM education.
- Environmental issues and global challenges.
- The role of STEM in nature and environmental education, and sustainability.

This introductory training aims to explain how the global understanding of green science has emerged within the framework of humanity's common problems and challenges. Within the context of this green science perspective, it emphasizes the importance of Green STEM as a pedagogical approach, highlighting its solution-oriented approach to global issues. By defining the impacts of green perspectives in different disciplines, it discusses how this concept originated, evolved, and is interpreted within various fields. Theoretical content provides teachers with a closer understanding of unique perspectives that can be brought through the Green STEM approach to environmental issues and global problems, supporting the development of a broader understanding in this regard. In this way, it presents a model for exploring nature, environmental education, and sustainability issues in learning environments as a holistic and innovative pedagogical approach within STEM education.

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TOPIC A.2: Introducing Teachers to the Professional Literature of Green STEM

Duration: 2 Hours

Outcomes:

- Understanding about Green STEM Research Landscape and Pipeline

Under the title of professional literature readings, the goal is to enable teachers to gain a deeper understanding of the conceptual framework by reading articles and current research reports on Green STEM topics. Selected article titles provide significant information related to sustainable development and environmental education. These articles cover various topics such as green chemistry, environmental awareness, climate change education, and sustainability. For instance, Kirsti Marie Jegstad and Astrid Tonette Sinnes' (2015) study titled "Chemistry Teaching for the Future" presents a model focused on sustainable development for secondary chemistry education. Laura B. Cole, G. Lindsay, and A. Akturk's (2020) article titled "Green building education in the green museum" explores green building education through design strategies in eight different museum examples. Dionysios Koulougliotis, LEMONIA Antonoglou, and Katerina Salta's (2021) study, "Probing Greek secondary school students' awareness of green chemistry principles," investigates the awareness of Greek secondary school students regarding green chemistry principles in projects associated with socio-scientific issues. Oliveira, A. W., and others (2023) address a data-intensive, issue-based atmospheric curriculum at the middle and high school levels using a weather-observing network in their article "The Backyard Weather Science Curriculum." These articles and others reflect various approaches to green STEM education, interdisciplinary perspectives on Green STEM studies, and diverse learning experiences in sustainability-related topics.



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TOPIC A.3: Green Learning Environments

Duration: 2 hours

Outcomes:

- Green building practices
- Green Campus / School concepts
- Green Gardens
- Green Museums and Public Engagement Learning Environments



The topic of this section is green buildings, which are built on a construction and design approach associated with sustainability. A green building is a structure designed, constructed, operated, and maintained based on principles of environmental sustainability and energy efficiency. These buildings are designed, constructed, and operated with the aim of minimizing environmental, economic, and social impacts and using resources in a balanced manner. Elements such as energy efficiency, water conservation, sustainable material usage, waste reduction, and indoor air quality form the foundation of green building standards. Green buildings reduce energy consumption, lower greenhouse gas emissions, promote sustainable resource use, and enhance the quality of life for individuals. Therefore, green buildings, and by extension, green campuses, serve as excellent examples of applying sustainability principles, protecting the environment, and enhancing societal well-being. Incorporating sustainability in school design serves as a learning tool to convey the importance of environmental conservation and sustainability to future generations. Universities are places where present and future decision-makers are educated, and societal values are shaped. People tend to adopt and normalize what they see and experience. Those who study in buildings committed to sustainability will likely spread this lifestyle to others, turning sustainability into a way of life.

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TOPIC A.4: Designing Green Labs

Duration: 2 hours

Outcomes:

- Introduction to Green Lab Concept
- Building a Green STEM lab.
- Conducting green experiments and projects.
- Accessing Green STEM Lab resources.



- Future directions & Sample Lab Designs

In this section, which focuses on the conceptual foundations and practical applications of green laboratories, the aim is to incorporate a series of technical and behavioral actions to reduce the amount of resources required for the laboratory to function safely and efficiently. Associating this section with Green STEM, the intention is to raise awareness about sustainability and environmental consciousness, promote the use of green technologies, design experiments with chemicals that are environmentally friendly or less harmful, and introduce exemplary practices in waste management while increasing energy efficiency. This approach aims to enhance the environmental awareness of teachers involved in educating future generations, making them more conscious about sustainability, and enabling them to impart this knowledge to their students. Additionally, the study is designed to provide content that can assist both students and teachers in enhancing their knowledge and skills in STEM fields. Within this framework, discussions will encompass green laboratory standards, certifications, training, and forms of establishment. Various teaching and learning approaches such as modeling, problem-based learning, technology-supported learning, and collaborative learning are employed in addressing the content of this section.

Key references:

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TOPIC A.5: Future Professions and Skills in STEM/Green STEM Fields

Duration: 2 hours

Outcomes:

- Promoting 21st century skills as qualifications expected from the workforce that can contribute to the global economy.
- Promoting green skills as the skills, values and attitudes that people need to support sustainable and effective use of resources in the workplace.



- Introducing the professions of the future in STEM/Green STEM fields.

The aim of this chapter is to introduce 21st century skills as the qualifications expected from the workforce that can contribute to the global economy, green skills as the abilities, values and attitudes that people need to support the sustainable and effective use of resources in the workplace, and the professions of the future in STEM/Green STEM fields. In addition, by ensuring that teachers are aware of all these skills and professions, it is to motivate teachers to frequently include Green STEM activities in their classes so that their students can gravitate towards these professions, which are pointed out as the professions of the future, and gain the necessary skills

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TOPIC A.6. Methods and Approaches that Can be Used in Green STEM Applications

Duration: 2 hours

Outcomes:

- Introducing the teaching methods/models and techniques underlying Green STEM activities.
- Providing examples of the application of teaching methods/models and techniques underlying Green STEM activities.
- Making connections between the teaching methods/models and underlying Green STEM activities and Green STEM activities themselves.

If teachers do not have sufficient knowledge and experience about instructional methods/models and techniques such as problem-based learning, inquiry-based learning, project-based learning, engineering design cycle, experiential learning, technology-enhanced learning, robotics and coding, simulations and modeling, and collaborative learning, understanding and implementing Green STEM activities can be quite challenging for them.



These instructional approaches serve as a foundation for teachers to implement Green STEM activities. The focus of this section, created based on this understanding, is to introduce teachers to the instructional approaches they need to be familiar with and able to implement in order to carry out Green STEM activities, providing usage examples.

Key references:

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TOPIC A.7: Integration of a Green STEM Activity into the Existing Science Education Curriculum

Duration: 2 hours

Outcomes:

- Understanding of current curriculum outcomes on the basis of Green STEM
- Inter-disciplinary approaches to Green STEM integration.

Many countries worldwide emphasize STEM education with the goal of cultivating individuals with the competencies needed for the future world and making efforts to enhance the quality of education. Despite significant evidence in the literature suggesting positive effects of STEM education on outcomes such as the development of 21st-century skills, fostering positive motivation and attitudes towards STEM as a career, improving technological literacy, and enhancing academic achievement, reports indicate that both pre-service and in-service teachers may be hesitant or inadequate in implementing STEM activities due to various reasons such as knowledge, experience, and anxiety levels.



In parallel with global developments, the Ministry of National Education in Turkey revised the middle school (grades 5-8) science curriculum in 2018, emphasizing "Science, Engineering, and Entrepreneurship Applications." However, according to literature studies, activities related to science, engineering, and entrepreneurship applications in textbooks are reported to be insufficient both in terms of quantity and in meeting STEM analysis criteria. It is suggested that teacher-centered practices still prevail as STEM activities. Therefore, there is a clear need for teachers to have examples to effectively plan and implement STEM practices.

In response to this need, this paper will propose an activity that can be transformed into a Green STEM application based on an activity found in one of the middle school science textbooks approved for use by the Ministry of National Education in Turkey.

Key references:

- Hiwatig, B. M., Roehrig, G., Ellis, J. A., Rouleau, M. (2022). Examining Student Cognitive Engagement in Integrated STEM (Fundamental). Presented Paper ID #37387, ASEE 2022 Annual Conference Excellence Trough Diversity, June 26th – 29th, Minneapolis, Minnesota.
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TOPIC A.8: Assessment in Green STEM Model

Duration: 2 hours

Outcome:

- Assessment of Green STEM Teaching and Learning Practices.

There is no complete consensus on the definition of STEM education in the literature, leading to various challenges in the assessment of STEM activities. To contribute to teachers' ability to evaluate a STEM activity or integrate a STEM activity into their plans, a proposed checklist based on the literature will be presented. This checklist will provide clues about what is expected from teachers and students in a STEM application. Therefore, the intention is for this checklist to serve as a guide for teachers and teacher candidates, aiming to characterize a STEM-integrated learning environment.



Key references:

- Sevgi Aydin Gunbatar, Betul Ekiz Kiran, Yezdan Boz & Gillian H. Roehrig (2022): A closer examination of the STEM characteristics of the STEM activities published in NSTA journals, *Research in Science & Technological Education*, DOI: 10.1080/02635143.2022.2121692
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MODUL B.

Sample Classroom Activities for Green STEM Practices

TOPIC B.1: Atmospheric Water Harvesting

Duration: 4 hours

Harvesting water from the atmosphere, also known as atmospheric water harvesting, is a process that involves extracting moisture from the air to obtain usable water. This innovative approach addresses water scarcity issues and provides 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), are employed for extracting water from the air. Condensation involves cooling the air to allow water vapor to condense into liquid form. Dew collectors use large surfaces to capture dew droplets formed overnight. Fog collectors use nets to capture water droplets from passing fog. AWGs utilize cooling or drying methods to extract water vapor from the air, which is then condensed and filtered to produce potable water. These methods are considered promising opportunities for sustainable water supply in arid, semi-arid, or coastal areas since they utilize the moisture present in the air to create freshwater sources. During the activity, teachers will be asked to design and prototype a water harvesting device to address the emerging issues of drought and associated water scarcity in their regions. Learning and teaching approaches such as problem-based learning, inquiry-based research, project-based learning, design thinking, engineering design, and hands-on science will be employed throughout the activity.

Key references:

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TOPIC B.2: Renewable energy sources: Salt Tower & 24/7 (uninterrupted) Solar Energy Usage

Duration: 4 hours

In this activity, a STEM project design is aimed at absorbing solar energy defined within the scope of renewable energy sources, which can be used during nights, cloudy, and rainy days, reducing the use of other energy sources that contribute to both energy continuity and environmental pollution. In the activity, different salts or salt mixtures with varying heat absorption properties will be used, with the help of mirrors, to absorb heat and aim to provide hot water/steam production or electricity generation by using the stored thermal energy after sunset or in situations where there is not enough solar energy. During these applications, the heat absorption properties of different salts and salt mixtures will be tested. These mixtures will be placed in salt towers designed in different forms, and the capacity of these towers to store solar energy will be tested by reflecting solar energy onto these towers with mirrors designed at different angles. The results obtained will be concluded through presentations, discussions, and evaluations of the efficiency of the product. This Green STEM project includes knowledge and acquisitions in the fields of natural sciences, engineering, technology, entrepreneurship, etc. Throughout the activity, learning and teaching approaches such as problem-based learning, inquiry-based research, project-based learning, engineering design, hands-on science, and technology-supported learning will be employed.

Key references:

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- Sheikh, K. (2016). New concentrating solar tower is worth its salt with 24/7 power. *Scientific American*, 14.

TOPIC B.3: Biomimicry: Nanofabrics & Environmental Industry Practices

Duration: 4 hours

This activity focuses on introducing students to water-repellent fabrics and the concept of biomimicry through a series of engaging sub-activities. In the first activity, students explore the importance of water-repellent fabrics by examining real-world examples and relatable scenarios. They observe the lotus effect, explaining situations where water beads up and rolls off the surface of lotus leaves. In the second activity, students learn the principles of the lotus effect and its application in nano water-repellent fabrics. They participate in interactive



sessions, brainstorm ideas, and discuss the characteristics of water-repellent fabrics. Additionally, the third activity encourages students to generate innovative design ideas for nano hydrophobic fabrics. In this regard, they transform their ideas into concrete prototypes of water-repellent fabrics using provided materials and tools. In the final activity, students assess the effectiveness of their nano hydrophobic fabric samples through water-based tests. The activity concludes with presentations, reflections, and a discussion about the biomimicry principles learned and the lessons about water-repellent fabrics and biomimicry. This Green STEM Project encompasses numerous gains in both knowledge and skills related to science, engineering, technology, mathematics, art, and entrepreneurship. Throughout the activity, various teaching and learning approaches such as problem-based learning, inquiry-based research, project-based learning, design thinking, engineering design, and hands-on science will be utilized.

Key references:

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TOPIC B.4: Environmental monitoring tools: Meriç River Water Quality

Duration: 4 hours

The activity addressing water pollution observed in the Meriç River can be implemented in various regions and expanded by focusing on other natural water sources in the vicinity. The goal is to understand and address water pollution issues in different geographical regions. Students will experience tools such as maps, GPS locators, water analysis kits, and water sample collection equipment. They will create a protocol to monitor water pollution levels in specific areas of the river. Additionally, a brainstorming session will be conducted to design a prototype for a water monitoring system, aiming for user-friendly, portable, and facilitative data collection processes. Students will field-test the designed water monitoring system, prepare a report including the results of their monitoring system, and provide recommendations regarding river pollution. This Green STEM Project encompasses numerous gains in both



knowledge and skills in the fields of science, engineering, technology, mathematics, art, and entrepreneurship. Throughout the activity, learning and teaching approaches such as problem-based learning, inquiry-based research, project-based learning, design thinking, engineering design, hands-on science, and technology-supported learning will be utilized.

Key references:

- Arabacioglu, S., & Unver, A. O. (2016). Supporting inquiry-based laboratory practices with mobile learning to enhance students' process skills in science education. *Journal of Baltic Science Education*, 15(2), 216.
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TOPIC B.5: Green Agriculture and Industrial Products: Pectins from Sunflower

Duration: 4 hours

Pectins are a natural polysaccharide family found in the cell walls of all plants and fruit peels. In the food industry, they are utilized as gelling agents, thickening agents, emulsifiers, and stabilizers. Pectin, particularly due to its ability to form a gel in conjunction with sugars, is widely used in the production of jams, marmalades, and jellies, as well as in fruit juices, dairy products, sauces, ketchup, mayonnaise, and bakery items. The primary countries engaged in pectin production worldwide include Mexico, Brazil, China, Switzerland, the United States, Argentina, and Italy. Turkey meets its pectin requirements in the food sector by importing pectin. Agricultural organic waste, especially fruit pomace, which becomes waste in the citrus and other fruit processing sectors, can be used for pectin isolation. Sunflower is one of the most cultivated agricultural products in the Thrace region, and after harvesting, the sunflower seeds are removed, leaving the stalk part in the field. The aim of this study is to obtain pectin from this agricultural organic waste. Following the experimental study, the characteristics of the obtained product will be examined, and an evaluation will be made according to the provided rubric. Throughout the activity, teachers and teacher candidates will be able to employ teaching approaches such as problem-based learning, inquiry-based research, project-based learning, and hands-on learning. The objective at the end of the activity is to increase awareness about recycling, impart knowledge and skills related to entrepreneurship, and promote efficient use of resources for life.



Key references:

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TOPIC B.6: Solar-Energy Food Dryer

Duration: 4 hours

Storing fruits and vegetables by drying has been a very ancient preservation method used since ancient times. In the drying process, the moisture level in food decreases to a level that inhibits the development of microorganisms. Although sun drying is a natural and common method, it brings along challenges such as being a time-consuming process, susceptibility to air pollution, microbial contamination, and exposure to external factors like insects. This situation has led to the need for the development of industrial drying machines that are faster and more hygienic. In this Green STEM activity, the aim is to design and prototype a completely solar-powered food dehydrator that can be used for the hygienic drying of fruits and vegetables, in addition to widely practiced activities such as making tomato paste and tarhana (Turkish traditional fermented soup), which hold significant places in the nutrition and economy of the people in Turkey during the summer for winter preparations. The designed product will be evaluated using a rubric developed according to the design criteria in the project. Throughout the activity, various learning and teaching approaches such as problem-based learning, inquiry-based research, project-based learning, design thinking, engineering design, applied learning (hands-on science), and technology-supported learning will be employed.

Key references:

- 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 Özbaltalı, N. (2019). Güneş enerjili kurutma teknolojileri ve uygulamalarda gelişmeler. 8. *Güneş Enerjisi Sistemleri Sempozyumu ve Sergisi*, 8-9 Kasım 2019, Mersin.
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TOPIC B.7: Production of Bioplastics for a Sustainable Future

Duration: Term Project

In today's world, many plastics are derived from non-renewable fossil sources, and their production is rapidly increasing. However, plastic waste has become a significant global issue, accumulating in both oceans and land, posing threats to both human life and the natural environment. Consequently, researchers from various fields worldwide have been working on solutions to address the plastic problem in recent years. Another challenge is the negative impact on various ecosystems due to the leakage water resulting from the disposal of organic waste into streets or landfills, leading to greenhouse gas emissions and adversely affecting ecosystems due to inadequate or limited waste management. One proposed solution to both issues is the utilization of organic waste with suitable properties for the production of bioplastics. Bioplastics are considered a promising sustainable alternative to traditional petroleum-derived plastics. This proposed project, spanning a period, aims to contribute to teachers' competence in preparing a project-based Green STEM activity plan by presenting an activity proposal for the sustainable production of bioplastics as a solution for environmental development.

Key references:

- Boisseaux, P. et al. (2023). Environmental safety of second and third generation bioplastics in the context of the circular economy. *Ecotoxicology and Environmental Safety*, 256, 114835. <https://doi.org/10.1016/j.ecoenv.2023.114835>
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- Merino, D. & Athanassiou, A. (2023). Thermomechanical Plasticization of Fruits and Vegetables Processing Byproducts for the Preparation of Bioplastics. *Advanced Sustainable Systems*, 7(9), 2300179. <https://doi.org/10.1002/adsu.202300179>



MODUL C. Assessment

Assessing the effectiveness of the Green STEM teacher program and providing guidance to teachers during classroom instruction can be achieved through various means. During workshops or seminars organized as part of the dissemination process of the Green STEM model, participating teacher groups may be expected to fulfill the following tasks:

- Participant engagement and attendance.
- Successful completion of hands-on Green STEM activities.
- Presentation of Green STEM project designs related to TOPIC 8-14.

To provide feedback and self-assessment for teachers in designing a Green STEM activity and adapting their classroom practices to the Green STEM model, it is recommended to use the checklist provided in the attachment, discussed in the "TOPIC A.8: Assessment in Green STEM Model" activity. This approach not only fosters a shared understanding of the Green STEM model among teachers but also enables the establishment of a common understanding applicable in classrooms related to the nature of traditional STEM education.

Program Completion:

Participants who successfully complete the workshops and seminars and meet the above mentioned assessment criteria will receive a “Green STEM Teacher Training” certificate.

GREEN STEM ACTIVITY DESIGN CHECKLIST - EN

CATEGORIES	ITEMS	EVALUATION		
Planning/preparation				
Planning of Outcomes	Does it include content outcomes?	Yes	No	NA
	Does it include procedural outcomes (scientific process skills / life skills / 21st-century skills, etc.)?	Yes	No	NA
	Does it include outcomes related to the nature of science?	Yes	No	NA
	Does it include outcomes related to the nature of technology?	Yes	No	NA
	Does it include outcomes related to the nature of engineering?	Yes	No	NA
	Does it include outcomes related to the nature of mathematics?	Yes	No	NA



	Does it include outcomes related to Green STEM?	Yes	No	NA
	Does it include outcomes related to other disciplines (art, entrepreneurship, etc.) beyond the above items?	Yes	No	NA
Planning of Methodology	Does it allow the use of inquiry-based research, argumentation, the 5E learning model, collaborative, problem-based, project-based learning methods, etc.?	Yes	No	NA
Planning of Assessment	Has the assessment of the product/solution been included in the plans?	Yes	No	NA
	Have the assessment of targeted outcomes been included in the plans?	Yes	No	NA
Process / Application				
Authentic Problem	Does it involve a real-life problem?	Yes	No	NA
	Has the problem been clearly and explicitly stated?	Yes	No	NA
	Is the problem conducive to proposing multiple solutions?	Yes	No	NA
	Does it provide opportunities for students to define/detect the problem?	Yes	No	NA
	Does it include limitations and/or allow students to identify the limitations of the problem?	Yes	No	NA
	Can the success of the solution/design be tested?	Yes	No	NA
Establishing a Relationship with Life	Is a relationship established between students' prior knowledge and experiences with the problem and/or solution?	Yes	No	NA
	Does it encourage students to understand the importance of the problem for society / environment / nature, etc.?	Yes	No	NA
Conducting research and developing multiple solutions	Is the teacher asking students questions to encourage them to think about what the problem is, its causes, and potential solutions?	Yes	No	NA
	Does the activity allow students the opportunity to ask questions?	Yes	No	NA
	Does the activity provide an opportunity for students to research and acquire new information about the problem and solution?	Yes	No	NA



	Does the activity allow flexibility for students to design their own solutions, including choices of materials and the design process?	Yes	No	NA
	Does the activity allow students to brainstorm and propose multiple solutions?	Yes	No	NA
	Does the activity provide opportunities for students to make evidence-based decisions, choices, or justifications?	Yes	No	NA
	Have criteria for evaluating the product/solution been presented to students at the beginning of the activity?	Yes	No	NA
Planning / Designing	Does the activity provide an opportunity to plan/design for the most suitable solution pathway?	Yes	No	NA
	Does the activity support students' creativity, collaborative work, and innovation skills?	Yes	No	NA
Implementation / Testing	Does it allow for testing and data collection opportunities?	Yes	No	NA
	Does it provide opportunities for analyzing data and making inferences?	Yes	No	NA
Evaluation of the Product / Solution	Does it allow for the evaluation of the product/solution pathway based on specific criteria?	Yes	No	NA
	Does it provide an opportunity for discussing the strengths and weaknesses of the product/solution pathway within the group by presenting evidence?	Yes	No	NA
Improvement	Does the activity provide an opportunity to plan/design the improvable aspects of the solution pathway?	Yes	No	NA
	Does it offer an opportunity to test/improve the design/solution pathway and collect data?	Yes	No	NA
Reflecting / Sharing	Does it provide an opportunity for sharing/presenting the solution pathway or product?	Yes	No	NA
	Does it allow for intergroup communication and interaction?	Yes	No	NA
	Does it provide an opportunity for evaluating the solution pathway/product among groups?	Yes	No	NA



Assessment of Outcomes	Does it facilitate the assessment of content acquisitions?	Yes	No	NA
	Does the activity allow for providing reflections on the process to students?	Yes	No	NA
Collaboration				
Student Group Work	Does the teacher allow students to work in small groups, providing opportunities for interaction and collaboration within the group?	Yes	No	NA
	Does the teacher facilitate intra-group and inter-group assessments?	Yes	No	NA
GREEN STEM ACTIVITY OVERALL EVALUATION CHECKLIST				
Is the STEM activity/plan aligned with the targeted content outcomes? (Does the STEM activity align with the learning objectives of the lesson?)		Yes	No	NA
Is the activity/plan suitable for the targeted procedural/skill outcomes?		Yes	No	NA
Do the lesson's outcomes directly contribute to solving STEM problems?		Yes	No	NA
Does it provide opportunities for acquiring new information?		Yes	No	NA
Does the activity allow for the assessment of the targeted outcomes?		Yes	No	NA
Does it create opportunities for students to use digital technology?		Yes	No	NA
Does the teacher encourage awareness of STEM careers?		Yes	No	NA
Does it provide opportunities for students to express reflective thinking? (Summary of the lesson or STEM activity, reflection on what was learned from the lesson or STEM activity.)		Yes	No	NA

* *Outcomes should be assessed considering the content, context, and content-context integration.*

Key References

- Sevgi Aydin Gunbatar, Betul Ekiz Kiran, Yezdan Boz & Gillian H. Roehrig (2022): A closer examination of the STEM characteristics of the STEM activities published in NSTA journals, *Research in Science & Technological Education*, DOI: 10.1080/02635143.2022.2121692
- Corlu, M. S. (2017). *STEM: Bütünleşik öğretmenlik çerçevesi* [STEM Kuram ve Uygulamaları içinde M. S. Corlu, & E. Çallı (Edit), Pusula Yayıncılık, İstanbul].
- Dare, E. A., Hiwatig, B., Keratithamkul, K., Ellis, J. A., Roehrig, G. H., Ring-Whalen, E. A., ... & Crotty, E. A. (2021). Improving integrated STEM education: The design and development of a K-12 STEM observation protocol (STEM-OP) (RTP). In *ASEE Annual Conference proceedings*.
- Ong, Y. S., Koh, J., Tan, A.-L., & Ng, Y. S. (2023). Developing an Integrated STEM Classroom Observation Protocol Using the Productive Disciplinary Engagement Framework. *Research in Science Education* <https://doi.org/10.1007/s11165-023-10110-z>



Couse Syllabus for Green STEM Training Program for Students of Pedagogical Sciences:
Sustainable Technologies in Science Education

COURSE SYLLABUS						
Sustainable Technologies in Science Education						
Study programme and level		Study field		Academic year	Semester	
Master Level 2 nd Cycle						
Lectures	Seminar	Lab Courses		Individ. work	ECTS	
30 h	15 h	30 h		75	5	

Content (Syllabus outline):

Green technologies, often referred to as sustainable or clean technologies, represent a diverse array of innovations aimed at mitigating environmental impact and promoting ecological sustainability. These technologies leverage advancements in science, engineering, and design to tackle urgent environmental challenges such as climate change, resource depletion, and pollution. The course will cover the following technologies:

Hydrogen Fuel Cells: Students will gain insight into this cutting-edge technology crucial for future sustainable energy. Fuel cells, electrochemical devices converting chemical energy into electricity, are explored with a focus on principles, types (e.g., proton-exchange membrane, solid oxide), efficiency, environmental benefits, and applications in transportation, power generation, and electronics. Challenges like cost and hydrogen production methods are discussed.

Electrolyzers: Students will learn about water electrolyzers using electrolysis to split water into hydrogen and oxygen. Fundamental concepts, types (alkaline, proton exchange membrane, solid oxide), efficiency, scalability, and economic aspects of water electrolysis are covered. Students engage with emerging research in materials science and catalyst design, gaining a holistic understanding of water electrolysis.

Lithium-ion (Li-ion) Batteries: The curriculum provides a comprehensive understanding of Li-ion batteries, covering electrochemical processes, ion migration, charge and discharge cycles, materials in electrodes, nanotechnology, safety considerations, and diverse applications. This knowledge equips students to contribute to the development and improvement of Li-ion battery technologies.

Sodium-ion (Na-ion) Batteries: Students gain a deep understanding of Na-ion batteries, exploring fundamental principles, electrochemical reactions, electrode and electrolyte materials, design considerations, advantages, challenges, and the latest research advancements. This knowledge positions students to comprehend the pivotal role of Na-ion batteries in shaping future energy storage technologies.

Beyond Li-ion Batteries: Students explore emerging technologies like solid-state batteries, novel materials (e.g., graphene), and next-generation battery chemistries (e.g., lithium-sulfur, lithium-air, redox flow, etc.) promising higher energy density, enhanced safety, and longer lifespan. The course aims to instill an understanding of these technologies surpassing current limitations and paving the way for more sustainable energy storage solutions.

Electrochemical (Micro)Reactors: Students gain insights into the design and fabrication of electrochemical (micro)reactors, exploring materials, manufacturing techniques, and integration methods. The course addresses applications ranging from energy conversion and storage to chemical synthesis and sensing.

Photovoltaics: Students learn to harness solar energy using PV technology. The curriculum covers basics, including sunlight conversion into electricity, the photovoltaic effect, solar cell design, materials



(e.g., silicon), and various technologies. Factors affecting solar cell efficiency, system components like inverters and batteries, and skills for solar PV system design and installation are discussed.

Wind Turbines: Students understand the technology, principles, and role of wind turbines in renewable energy. The curriculum covers aerodynamics, design considerations, various turbine types, and integration into the energy grid, including storage and challenges with changing wind speeds.

The course emphasizes hands-on experiences, encouraging students to build, test, and analyze green technology systems using students' project-based learning. This approach fosters a practical understanding of the technologies' real-world applications and stimulates critical thinking about their role in a sustainable energy future.

Literature:

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.

Objectives and competences:

Objectives:

- Understand Sustainable Energy Concepts
- Understand the principles of hybrid renewable energy systems.
- Design and analyze 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.
- Analyze 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 electrolyzers.
- Compare and contrast lithium-ion batteries with emerging battery technologies.
- Analyze 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.
- Analyze 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.

Competences:

- Understand the principles of hybrid renewable energy systems.
- Design and analyze integrated systems combining multiple sustainable technologies.
- Understand the principles of hybrid renewable energy systems.
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- Understand the principles of hybrid renewable energy systems.
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- Understand the principles of hybrid renewable energy systems.
- Design and analyze integrated systems combining multiple sustainable technologies.

Intended learning outcomes:

Learning outcomes aim to provide students with a comprehensive and well-rounded understanding of sustainable technologies, preparing them to contribute to the advancement and application of these technologies in various scientific and engineering contexts including:

- Demonstrate a deep understanding of the principles and concepts underlying sustainable technologies in the fields of hydrogen fuel cells, electrolyzers, batteries (including lithium and beyond lithium technologies), electrochemical microreactors, photovoltaics, and wind turbines.
- Identify and explain the key components, materials, and processes involved in each technology.
- Evaluate the efficiency and effectiveness of various sustainable technologies in comparison to conventional energy sources.
- Demonstrate hands-on skills in operating and assembling hydrogen fuel cells, electrolyzers, batteries, electrochemical microreactors, photovoltaic systems, and wind turbines.
- Design and conduct experiments to investigate the performance and efficiency of sustainable technologies.
- Assess and address challenges and limitations associated with the implementation of sustainable technologies.



- Recognize the interdisciplinary nature of sustainable technologies, integrating knowledge from chemistry, physics, engineering, and environmental science.
- Effectively communicate scientific concepts and findings related to sustainable technologies through written reports, oral presentations, and visual aids.
- Collaborate with peers in group projects, fostering teamwork and effective communication.
- Stay informed about the latest advancements in sustainable technologies beyond the course content, including emerging trends and cutting-edge research.

Learning and teaching methods:

1. Lectures supported by multimedia materials (30h).
2. Students actively participate and in groups develop their own projects. Firstly, students are acquainted with the examples in step-by-step instruction of lab exercises (15h lab courses), followed by developing their own projects. Project-based learning takes place partly in the computer classroom (15h seminar) and partly in the chemistry laboratory (15h lab courses).
3. Implementation of the course is supported using Learning Management System Moodle and collaborative learning environment MS Teams.

Weight (in %)	Assessment:
50%	Written exam
40%	Project portfolio
10%	Project presentation



Co-funded by
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TEACHING MATERIALS AND EXAMPLES OF GOOD PRACTICES



TEACHING MATERIALS AND EXAMPLES OF GOOD PRACTICES

Teaching materials for Green STEM Training Program for Students: Innovative course in Green STEM for student training

Example: Utilizing Solar Energy

Description of Innovative Green STEM teaching/learning unit for Students

Educational level (students' age): UNIVERSITY LEVEL (AGES 18+)	
Subject: GREEN STEM	
Topics: UTILIZING SOLAR ENERGY: <i>SOLAR PHOTOVOLTAIC CELLS</i>	
Curriculum objectives:	
<ul style="list-style-type: none"> ● Understanding the Principles and functionality of Solar Panels by harnessing sunlight for electricity generation. ● Exploring Solar thermal technologies for domestic and industrial applications. Determining the efficiency of Solar Water Heaters. ● Designing and Constructing Solar Chargers, Lights, and Gadgets. ● Connecting theoretical knowledge of solar energy systems with its practical applications in everyday life. ● Expanding the environmentally friendly green scientific knowledge, technical skills and also cultivate a deeper appreciation for sustainable living. ● Conducting research experiments to verify the composition and some of the properties of solar cells. 	
Key words:	
Solar energy utilization, photovoltaic cells, solar thermal technologies, solar-powered devices	
Learning tools:	
<ul style="list-style-type: none"> ● Solar photovoltaic cell model ● Educational videos or animations demonstrating solar panel operation ● Solar Water Heating Systems ● Solar-Powered Devices ● Data collection tools for measuring of the impact of various parameters such as light intensity, temperature, and material characteristics used in constructing the solar photovoltaic cells 	
Literature resources for students	



obligatory:

- Anderson, T. M. (Ed.). (2017). Solar Cell Efficiency: A Comprehensive Guide. Springer.
- Huang, J., & Fu, L. (2020). Advances in Photovoltaics: Part 1. Elsevier.
- Johnson, J. D., & Smith, A. B. (2019). Solar Energy: Principles and Applications. Wiley.

additional:

- Miller, G. H. (2017). Solar Energy Engineering: Processes and Systems. Academic Press.
- Smith, C. R., & Jones, E. F. (2018). Introduction to Renewable Energy Technologies. Cambridge University Press.

Literature resources for (future) teachers

obligatory:

- https://www.mozaweb.bg/en/Extra-3D_scenes-How_does_it_work_Photovoltaic_solar_panel_solar_thermal_collector-146845
- <https://www.mozaweb.bg/en/Microcurriculum-364681>
- <https://www.mozaweb.bg/en/Microcurriculum-583045>
- Jones, S. R., & Brown, K. L. (2019). Solar Power Engineering: Processes and Systems. CRC Press.

additional:

- Taylor, R., & Thompson, L. (2020). Photovoltaic Solar Energy Conversion: Basic Principles, Technologies, and Systems. CRC Press.
- Wang, Y., & Huang, C. (Eds.). (2018). Solar Cell and Renewable Energy Experiments. Springer.

Teaching method(s):

1. **Hands-on Demonstrations:** Conduct hands-on demonstrations where students can observe how solar photovoltaic cells work. Provide them with solar panels and simple circuit components to build their own small-scale solar power systems.
2. **Experimental Learning:** Design experiments where students can investigate factors affecting the efficiency of solar cells, such as sunlight intensity, angle of incidence, and temperature. Encourage them to collect and analyze data to draw conclusions about optimal conditions for solar energy generation.
3. **Problem-Based Learning (PBL):** Present real-world scenarios related to solar energy utilization, such as designing a solar-powered charging station or optimizing the placement of solar panels on a building. Have students work in groups to brainstorm solutions, conduct research, and propose innovative designs.
4. **Simulation Software:** Utilize simulation software or online tools that allow students to simulate the operation of solar photovoltaic systems. This enables them to explore different configurations and settings virtually, helping them understand the underlying principles of solar energy conversion.



5. **Field Trips and Guest Speakers:** Organize field trips to solar power plants or invite guest speakers from the renewable energy industry to share their experiences and insights with students. This provides valuable real-world context and exposes students to career opportunities in the field of solar energy.
6. **Project-Based Learning (PBL):** Engage students in project-based learning activities where they design, build, and test their own solar-powered devices or systems. This could include constructing solar ovens, solar water heaters, or portable solar chargers, fostering creativity and problem-solving skills.
7. **Interactive Lectures:** Deliver interactive lectures using multimedia presentations, videos, and demonstrations to explain the scientific principles behind solar photovoltaic technology. Encourage active participation through discussions, quizzes, and concept mapping exercises to reinforce learning.

Scenario of Green STEAM teaching/learning unit

Phase	Required time	Teachers' activity	Students' activity
Introduction	5 minutes	Directing students' attention to various renewable energy sources, emphasizing the utilization of solar energy as a clean and essential source of renewable energy.	Students will be able to distinguish the finite energy resources and renewable energy sources and to give the benefits of a solar source of power that holds the key to a cleaner and greener future.
Exploration	10 minutes	Introduce the concept of solar energy and photovoltaic cells through multimedia presentations and interactive discussions. Provide background information on the principles of solar energy conversion and the components of solar photovoltaic systems.	Engage in hands-on activities such as building simple solar-powered devices or conducting experiments to explore the factors affecting solar energy generation. Collaborate in small groups to research and present their findings on the applications and benefits of solar photovoltaic technology.
Design and Construction	40 minutes	Guide students in designing their own solar energy projects, such as solar-powered chargers, model solar cars, or solar water heaters. Provide assistance in selecting appropriate materials, understanding circuit diagrams, and troubleshooting technical challenges.	Work in teams to brainstorm ideas, create design sketches, and build prototypes of their solar energy projects. Apply principles of engineering and design thinking to optimize the efficiency and functionality of their creations. Test and refine their prototypes based on performance evaluations and feedback.



<p>Energy Simulation Activity</p>	<p>15 minutes</p>	<p>Introduce a hands-on simulation activity where students use simple materials to understand the principles of solar energy conversion. Provide instructions and guidance on setting up the simulation and facilitate the activity to ensure students grasp key concepts.</p>	<p>Engage in a brief hands-on activity where they simulate the process of converting sunlight into electricity using simple materials such as mirrors, magnifying glasses, and small solar panels. Observe the effects of sunlight intensity and angle on electricity generation and discuss their findings with peers.</p>
<p>Data Collection and Analysis</p>	<p>20 minutes</p>	<p>Facilitate data collection activities where students measure sunlight intensity, temperature, and other relevant variables using sensors and data logging equipment. Provide guidance on data analysis techniques and statistical methods for interpreting experimental results.</p>	<p>Conduct field observations and experiments to gather data on solar energy availability and performance of photovoltaic systems in different environmental conditions. Analyze and visualize data using software tools to identify patterns and correlations, drawing conclusions about the effectiveness of solar energy utilization.</p>

Appendix 1:

Instructions for Students

- **Introduction to Solar Energy:** Brief overview of solar energy and its importance.
- **Solar Photovoltaic Cells:** Explanation of how solar cells work and their applications.
- **Hands-on Activity Guide:** Step-by-step instructions for conducting the solar energy simulation activity.
- **Data Collection Sheet:** Template for recording observations and data during the simulation activity.
- **Reflection Questions:** Prompts for students to reflect on their learning and the significance of solar energy.

Materials for Teachers

- **Solar Energy Simulation Kit:** Includes mirrors, magnifying glasses, small solar panels, and other necessary materials for the hands-on activity.
- **Instruction Manual:** Detailed guide for setting up and conducting the simulation activity, including safety precautions.
- **Presentation Slides:** PowerPoint or Google Slides presentation for introducing key concepts and guiding the discussion.
- **Data Analysis Tools:** Spreadsheet templates or data analysis software for processing and analyzing the collected data.
- **Additional Resources:** Links to online resources, books, or articles for further reading on solar energy and photovoltaic cells.



Appendix 1.

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. Using 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.

REFERENCES

- Anderson, T. M. (Ed.). (2017). *Solar Cell Efficiency: A Comprehensive Guide*. Springer.
https://www.mozaweb.bg/en/Extra-3D_scenes-How_does_it_work_Photovoltaic_solar_panel_solar_thermal_collector-146845
<https://www.mozaweb.bg/en/Microcurriculum-364681>
<https://www.mozaweb.bg/en/Microcurriculum-583045>
- Huang, J., & Fu, L. (2020). *Advances in Photovoltaics: Part 1*. Elsevier.
- Johnson, J. D., & Smith, A. B. (2019). *Solar Energy: Principles and Applications*. Wiley.
- Jones, S. R., & Brown, K. L. (2019). *Solar Power Engineering: Processes and Systems*. CRC Press.
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- Taylor, R., & Thompson, L. (2020). *Photovoltaic Solar Energy Conversion: Basic Principles, Technologies, and Systems*. CRC Press.
- Wang, Y., & Huang, C. (Eds.). (2018). *Solar Cell and Renewable Energy Experiments*. Springer.



Example: Harnessing Wind Power

Description of Innovative Green STEM teaching/learning unit for Students

Educational level (students' age): UNIVERSITY LEVEL (AGES 18+)
Subject: GREEN STEM
Topics: HARNESSING WIND POWER: WIND TURBINE MODEL KIT
<p>Curriculum objectives:</p> <ul style="list-style-type: none"> ● Understanding the principles of wind energy conversion and the function of wind turbines. ● Investigating the factors that affect wind turbine performance, such as blade design, wind speed, turbine placement, and electrical loads. ● Applying STEM concepts to analyze data collected from wind turbine experiments. ● Developing problem-solving skills by proposing solutions to optimize wind turbine efficiency and energy production. ● Enhancing practical skills through hands-on experimentation with the wind turbine model kit. ● Fostering critical thinking and inquiry skills by formulating hypotheses and conducting experiments to test them. ● Promoting collaborative learning and teamwork by engaging in group-based wind turbine projects. ● Connecting theoretical knowledge of renewable energy concepts to real-world applications in wind power generation. ● Cultivating an awareness of environmental sustainability and the importance of renewable energy sources like wind power. ● Encouraging creativity and innovation in designing and testing wind turbine prototypes.
<p>Key words:</p> <p>Wind energy, Wind turbine, Renewable energy, Energy conversion, STEM concepts, Data analysis, Problem-solving, Hands-on experimentation, Real-world applications, Environmental sustainability</p>
<p>Learning tools:</p> <ul style="list-style-type: none"> ● Wind turbine model kits ● Educational videos or animations demonstrating wind turbine operation ● Interactive simulations of wind turbine performance ● Data collection tools for measuring wind speed and electrical output ● Experimentation kits for exploring blade designs and turbine placement



Literature resources for students

obligatory:

- Chiras, D. (2019). Wind Power Basics: A Green Energy Guide. New Society Publishers.
- Manwell, J. F., McGowan, J. G., & Rogers, A. L. (2010). Wind Energy Explained: Theory, Design and Application. Wiley.
- Wagner, H. J., & Mathur, J. (2013). Introduction to Wind Energy: Renewable Energy Applications. Springer.

additional:

- Burton, T., Jenkins, N., Sharpe, D., & Bossanyi, E. (2011). Wind Energy Handbook. Wiley.
- Musgrove, P. (2019). Wind Energy Essentials: Societal, Economic, and Environmental Impacts. CRC Press.
- Nelson, V., & Starcher, K. (2015). Wind Energy: An Introduction. Cambridge University Press.

Literature resources for (future) teachers

obligatory:

- Ackermann, T. (2011). Wind Power in Power Systems. Wiley.
- Garcia-Sanz, M., & Houpis, C. H. (2013). Wind Energy Systems: Control Engineering Design. CRC Press.
- Schaefer, C., & Plotkin, A. (2017). Teaching Wind Energy. Routledge.

additional:

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Teaching method(s):

- **Hands-on Demonstrations:** Engage students in building and testing wind turbine models, integrating STEM principles into practical applications;
- **Experimental Learning:** Encourage students to conduct experiments with the wind turbine model kit, exploring various factors affecting its efficiency and performance, fostering a deeper understanding of STEM concepts;
- **Group Work:** Foster collaborative activities where students work together to assemble and test the wind turbine model, promoting teamwork and communication skills within a STEM context;
- **Problem-Based Learning:** Present students with real-world challenges related to wind energy and task them with applying their STEM knowledge and skills to find solutions using the model kit;
- **Discussion and Reflection:** Facilitate discussions about the principles behind wind energy, the design of wind turbines, and the implications for renewable energy, followed by reflection on their learning experiences, promoting critical thinking and STEM literacy.



Scenario of Green STEAM teaching/learning unit

Phase	Required time	Teachers' activity	Students' activity
Introduction	5 minutes	Introduce the concept of green energy and its importance in sustainability. Present various forms of green energy, with a focus on wind energy.	Engage in discussions about the environmental impact of traditional energy sources and the benefits of green energy alternatives.
Exploration	10 minutes	Facilitate discussions on the principles of wind energy and the design of wind turbines. Provide background information on STEM concepts related to wind energy.	Explore interactive simulations or models demonstrating wind energy generation. Collaborate in small groups to brainstorm ideas for designing and building their own miniature wind turbines. Conduct fast research on wind turbine technology, materials, and environmental considerations.
Design and Construction	40 minutes	Provide guidance on the engineering design process, emphasizing the importance of innovation and sustainability. Offer technical support and resources for students to develop their wind turbine designs. Facilitate discussions on project planning, budgeting, and safety protocols.	Work in teams to refine their wind turbine designs based on research and feedback. Utilize STEM skills to construct prototypes of their wind turbines using provided materials or renewable resources. Document the design process through sketches, diagrams, and written explanations. Test and iterate on their prototypes to optimize performance and energy efficiency.
Experimentation and Optimization	20 minutes	Provide students with wind turbine model kits and access to testing equipment. Demonstrate proper procedures for setting up and conducting wind turbine performance tests. Guide students through the process of designing experiments to investigate factors	Work in small groups to design and carry out experiments to measure the performance of their wind turbine models. Test different variables, such as blade length, number of blades, and turbine height, to optimize power output. Collect and analyze data from their experiments using scientific methods and tools.



		affecting turbine efficiency, such as blade angle and wind speed.	Modify their turbine designs based on experimental results and iterate on testing to improve performance.
Testing and Evaluation	15 minutes	Coordinate testing environments and equipment for evaluating wind turbine performance. Guide students in collecting and analyzing data from their wind turbine tests. Facilitate discussions on the significance of data analysis in assessing the effectiveness of their designs.	Conduct experiments to measure the power output and efficiency of their wind turbines under various wind conditions. Record and interpret data to determine the strengths and weaknesses of their designs. Reflect on their testing results and identify areas for improvement in their wind turbine designs.

Appendix 1:

Instructions for Students

- Assemble your wind turbine model kit according to the provided instructions.
- Familiarize yourself with the components of the wind turbine and how they function.
- Conduct preliminary tests to ensure that your wind turbine is functioning properly.
- Design and carry out experiments to investigate factors affecting turbine performance, such as blade design, turbine height, and wind speed.
- Record data from your experiments accurately and analyze the results.
- Modify your turbine design based on experimental findings to optimize performance.
- Prepare a report or presentation summarizing your findings and conclusions from the experimentation process.

Materials for Teachers

- **Wind Turbine Model Kits:** Provide kits containing all necessary components for building and testing wind turbines, including blades, hub, generator, and tower.
- **Testing Equipment:** Ensure access to instruments for measuring wind speed, turbine rotation speed, and power output, such as anemometers, tachometers, and multimeters.



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- **Instructional Resources:** Prepare instructional materials, including handouts, presentations, and videos, to supplement student learning and provide guidance throughout the unit.
- **Safety Guidelines:** Establish safety protocols and guidelines for handling equipment and conducting experiments to ensure the well-being of students and teachers.
- **Assessment Rubrics:** Develop rubrics or scoring guides to assess student performance and understanding throughout the unit, including criteria for experimentation, data analysis, and presentation skills.



Appendix 1.

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 CO₂ 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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Description of Innovative Green STEM teaching/learning unit for Students

Educational level (students' age): UNIVERSITY LEVEL (AGES 18+)
Subject: GREEN STEM
Topics: THE IMPACT OF CO ₂ FOOTPRINT AND IMPLEMENTING REDUCTION STRATEGIES: ENERGY EFFICIENCY AND CO ₂ EMISSIONS MONITORING WITH STEM TOOLS
<p>Curriculum objectives:</p> <ul style="list-style-type: none"> ● revealing the theoretical basis of energy monitoring and CO₂ emissions, using STEM tools; ● analyzing data and proposing solutions for a greener future; ● developing a holistic understanding of the factors influencing energy consumption and environmental impact.
<p>Key words: CO₂ emissions monitoring, STEM tools, environmental science, greenhouse gas emissions, energy consumption, energy-saving strategies</p>
<p>Learning tools:</p> <ul style="list-style-type: none"> • STEM tools for energy monitoring (e.g., energy meters, smart plugs, environmental sensors equipped with CO₂ sensors); • Paper and pen for recording data / Computer with Microsoft Excel program; <p>Utility bills, online monitoring platforms.</p>
<p>Literature resources for <i>students</i></p> <p>obligatory: Anderson, B. D., & Wu, L. (2017). CO₂ Emissions Reduction in Transportation: Policies and Technologies. Springer. Brown, E. R. (2018). STEM Education: Concepts, Methodologies, Tools, and Applications. IGI Global.</p> <p>additional: Gupta, R. K., & Tiwari, G. N. (Eds.). (2019). Monitoring and Reduction of CO₂ Emissions in Energy Systems. Springer. Jackson, C. A., & Smith, P. L. (2020). Monitoring Carbon Dioxide Emissions: Methods and Applications. CRC Press. https://www.mozaweb.bg/en/Microcurriculum/view?azon=dL_513</p>
<p>Literature resources for (future) <i>teachers</i></p> <p>obligatory: Johnson, T. H., & Williams, R. D. (2017). CO₂ Emissions Monitoring Techniques: A Comprehensive Overview. Wiley.</p>



Khan, M. E., & Hanjra, M. A. (2018). Sustainable Management of CO2 Emissions: Methods and Strategies. Routledge.

additional:

Li, X., & Fang, Y. (2019). Energy Efficiency Monitoring and Management in Industrial Systems. Elsevier.

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<https://www.nature.org/en-us/get-involved/how-to-help/carbon-footprint-calculator/>

Teaching method(s):

- Problem-Based Learning;
- Inquiry-Research;
- Project-Based Learning;
- Design Thinking and Engineering Design;
- (Hands-on Science) Applied Learning;
- Technology-Assisted Learning.

Scenario of Green STEAM teaching/learning unit

Phase	Required time	Teachers' activity	Students' activity
Introduction	5 minutes	Introducing the idea of the impact of carbon dioxide (CO ₂) emissions on the environment and exploring practical measures to reduce the carbon footprint. Presenting the interconnectedness between human activities and climate change, with a specific focus on the role of CO ₂ emissions.	Engage students attention 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.
Exploration	10 minutes	Discussions to understand and mitigate the environmental impact of human activities, particularly in terms of carbon emissions.	Collaborative activities to explore interactive simulations or models demonstrating practices and technologies that minimize energy consumption and CO ₂ emissions, thereby mitigating environmental harm and promoting sustainability. Proposing solutions for reducing carbon emissions.
Design and Construction	40 minutes	Provide guidance on the CO ₂ Emissions Monitoring with STEM Tools. Introduce students to smartphone apps designed for tracking carbon footprint. Engage students	Work in teams: equipped with STEM tools students are allowed to simultaneously measure energy consumption and CO ₂ emissions in the classrooms.



		with the sustainable transportation challenge using smartphone apps and GPS tracking tools.	Using the "Capture" or "Footprint" apps to calculate their carbon emissions, including transportation, energy consumption, and food choices. Through data collection and analysis, students 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.
Experimentation and Optimization	20 minutes	Provide students with STEM tools to measure and analyze energy consumption. Demonstrate proper procedures for monitoring CO ₂ emissions. Guide students through the process of investigating energy-saving strategies and analyzing data followed by proposing solutions.	Work in small groups to use STEM tools to collect data on energy usage in different areas of the university campus or home, including electricity, heating, and transportation. Analyzing the data to identify trends and patterns in energy consumption. Discussing and comparing CO ₂ emission levels between different activities and identify sources of high emissions. The students utilize STEM tools to measure and monitor CO ₂ emissions associated with energy usage and transportation. They test different variables and discuss implementation of 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. Finally, students collect and analyze the collected data to identify areas for improvement and propose solutions to reduce energy consumption and CO ₂ emissions. They develop action plans for implementing changes to promote energy efficiency and sustainability.
Testing and Evaluation	15 minutes	Coordinate actions on measuring the energy consumption. Guide students in monitoring CO ₂ emissions investigating energy-saving strategies. Facilitate the process of discussions, data analysis and solutions proposition.	Conduct experiments with energy meters and smart plugs to measure electricity usage. Record and Compare energy consumption between different areas or devices to prioritize areas for energy-saving interventions. Analyse and discuss the collected data to identify trends and correlations between energy consumption, CO ₂ emissions, and implemented strategies.



			Make decisions and propose action plans for further reducing energy consumption and CO ₂ emissions, considering factors such as feasibility, cost-effectiveness, and environmental impact.
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Appendix 1:

Instructions for Students

- Assemble your energy meters and environmental sensors equipped with CO₂ sensors according to the provided instructions.
- Familiarize yourself with the smartphone apps "Capture" and "Footprint" designed for tracking carbon footprint.
- Conduct preliminary tests to ensure that the STEM tools for energy and carbon monitor is functioning properly.
- Design and carry out experiments to investigate factors affecting the STEM tools performance.
- Record data from your experiments accurately and analyze the results.
- Prepare a report or presentation summarizing your findings and conclusions from the experimentation process.

Materials for Teachers

- **Energy Meters:** Provide kits equipped with the necessary components and instructions for proper use.
- **Environmental sensors equipped with CO₂ sensors:** Provide kits equipped with the necessary components and instructions for proper use.
- **Smartphone apps "Capture" or "Footprint"** designed for tracking carbon footprint. Provide students with instructions about the apps utilisation.
- **Testing Equipment:** Ensure access to instruments for Energy and CO₂ measuring.
- **Instructional Resources:** Prepare instructional materials, including handouts, presentations, and videos, to supplement student learning and provide guidance throughout the unit.
- **Safety Guidelines:** Establish safety protocols and guidelines for handling equipment and conducting experiments to ensure the well-being of students and teachers.



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- **Assessment Rubrics:** Develop rubrics or scoring guides to assess student performance and understanding throughout the unit, including criteria for experimentation, data analysis, and presentation skills.





Appendix 1.

EXERCISE 3: The Impact of CO₂ 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 (CO₂) 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 CO₂ 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 CO₂ FOOTPRINT AND IMPLEMENTING REDUCTION STRATEGIES":

Resource 1: *Energy Efficiency and CO₂ Emissions Monitoring with STEM Tools:* Provide students with STEM tools such as energy meters or environmental sensors equipped with CO₂ sensors that can be connected to smartphones or tablets. Students can use these tools to simultaneously measure energy consumption and CO₂ emissions in different areas of their school or home, such as classrooms, laboratories, or common areas. By collecting and analyzing energy data alongside CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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 CO₂ emissions over time?



5. What are the differences in energy consumption and CO₂ emissions between weekdays and weekends, and how can energy-saving practices be tailored to accommodate these variations?
6. How do transportation choices impact overall CO₂ 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 CO₂ emissions?
8. What role can data visualization and analysis play in raising awareness about energy usage and CO₂ 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 CO₂ emissions in our community?

Resource 1

ENERGY EFFICIENCY AND CO₂ 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 CO₂ Emissions Monitoring With Stem Tools," provides students with hands-on experience in monitoring and analyzing energy consumption and CO₂ 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 CO₂ emissions are paramount for sustainability. Through this project, students will delve into the theoretical



basis of energy monitoring and CO₂ emissions, using STEM tools to analyze data and propose solutions for a greener future.

Energy efficiency and CO₂ 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 CO₂ 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 CO₂ emissions: Utilize STEM tools to measure and monitor CO₂ emissions associated with energy usage and transportation. Compare CO₂ 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 CO₂ emissions.
4. Analyze data and propose solutions: Analyze the collected data to identify areas for improvement and propose solutions to reduce energy consumption and CO₂ 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 CO₂ emissions with STEM tools, will lead to a measurable reduction in both energy consumption and CO₂ 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 CO₂ EMISSIONS

Required materials:

- CO₂ 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 CO₂ emissions to be monitored, such as transportation or energy usage.
2. Install CO₂ monitoring devices or sensors in relevant areas (e.g., vehicles, classrooms) to measure CO₂ emissions.
3. Record baseline CO₂ emission data over a set period (e.g., one week) using STEM tools.



4. Analyze the collected data to identify sources of high CO₂ emissions and potential areas for improvement.
5. Compare CO₂ emissions between different activities or modes of transportation to prioritize areas for emission reduction.
6. Use the data to develop strategies for reducing CO₂ 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 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, CO₂ emissions, and the effectiveness of energy-saving strategies.
2. Analyze the data to identify trends, patterns, and correlations between energy consumption, CO₂ emissions, and implemented strategies.
3. Evaluate the success of implemented strategies in achieving energy efficiency and reducing CO₂ 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 CO₂ 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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Description of innovative Green STEAM teaching/learning unit

Educational level (students' age): Middle School
Subject: Green STEM
Topics: Renewable energy sources Salt Tower & 24/7 (uninterrupted) Solar Energy Usage
<p>Curriculum objectives:</p> <p>Science Objectives:</p> <ul style="list-style-type: none"> • Acquires basic knowledge about salt towers and solar energy • Understands the importance of energy storage in solar energy • Understands heat transfer, energy conversion, and renewable energy topics • Gains awareness about environmentally friendly energy sources. <p>Engineering Objectives:</p> <ul style="list-style-type: none"> • Acquires skills to design and construct salt towers • Gains engineering skills, observes and understands engineering applications • Knows material selection, building construction, and solar energy collection methods • Acquires creative thinking and problem-solving skills when designing energy storage systems. <p>Technology Objectives:</p> <ul style="list-style-type: none"> • Understands solar energy storage technologies • Recognizes the importance of solar energy mapping areas • Can utilize solar energy mapping systems. <p>Art Objectives:</p> <ul style="list-style-type: none"> • Recognizes the importance of aesthetic appearances of produced products. <p>Related Green Deal Strategies: 2.1.2. Clean, affordable, and secure energy.</p>
Key words: Solar energy, solar energy storage, absorption, types and characteristics of salts, zero emissions, mirrors and their properties, absorption, solar energy mapping



<p>Learning tools:</p>	<p>Student worksheet 1-3 https://globalsolaratlas.info/map?c=41.374748,27.103271,9&s=41.695475,26.608887&m=site</p>	<p>Different sized concave mirrors Various salt samples such as NaCl, NaNO₃, Ca(NO₃)₂, KCl, MgCl₂ Adhesives Metal cylinders in different sizes Thin-walled copper pipes Aquarium pump Digital thermometer Beaker Erlenmeyer flask Aluminum foil Digital scale Plastic or glass bottles for providing water circulation</p>
<p>Literature resources for students https://globalsolaratlas.info/map?c=41.374748,27.103271,9&s=41.695475,26.608887&m=site</p>		
<p>Literature resources for (future) teachers Güven, Ş. Y., Üçgül, İ., & Şenol, R. (2004). Güneş enerjisi ısı uygulamaları ve güneş kulelerinin incelenmesi. <i>Mühendis ve Makina</i>, 45(533), 17-28. Akçalı, G., 2001. “Güneş enerjisi sistemleri”, İstanbul Ticaret Odası. Dinçer, F., “Türkiye”de güneş enerjisinden elektrik üretimi potansiyeli- ekonomik analizi ve AB ülkeleri ile karşılaştırmalı değerlendirme”, KSU Mühendislik Dergisi, 14 (1), 2011. https://ticaret.gov.tr/dis-iliskiler/yesil-mutabakat Leblebicioğlu, E., 2017. “Güneş Güç Kulesi Sistemleri,” Erişim Tarihi: 18/09/2020. https://muhendistan.com/gunes-kulesi-sistemleri/. Adıyaman, G., Horuz, İ., & Çolak, L. (2018). Technical and Environmental Evaluation of Heat Transfer Fluids Used in Solar Power Towers. <i>Proc. ICCE-2018, North Cyprus</i>. https://globalsolaratlas.info/map?c=41.374748,27.103271,9&s=41.695475,26.608887&m=site Messadi A, Timoumi Y., “Improvement of the Solar Rankine Cycle Applying to the Solar Power Station: Solar II.” <i>Innov Ener Res</i> 7: 198, 2018.</p>		



Teaching method(s) :	Throughout the activity; learning and teaching approaches such as problem-based learning, inquiry-based research, project-based learning, engineering design, hands-on science, and technology-supported learning will be utilized.
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Yeşil STEAM öğretim/öğrenme birimi senaryosu

Phase	Required time	Teachers' activity	Students' activity
Identifying the Problem	30 min	In today's world, energy demand is steadily increasing and this increase seems likely to continue. Energy obtained from different sources can, however, harm the environment. Among these sources, solar energy stands out as an infinite and clean energy source. Therefore, we need to harness solar energy more effectively. The teacher demonstrates why solar energy is important compared to other energy sources through applications in their own local environment. They emphasize the importance of storing solar energy and provide students with the opportunity to discuss and debate methods for storing solar energy to be used during hours when the sun is not available.	Students recall the importance of energy and different types of energy, and they research which types of energy serve as clean energy sources. Working in groups or individually, they engage in knowledge sharing by discussing the significance and applications of solar energy. Moreover, students are provided with the opportunity to examine the efficiency and potential of solar energy in their region, country, and neighboring countries. Additionally, they investigate the heat retention potentials of various materials. Known information and emerging perspectives related to the problem scenario are recorded in Student Worksheet 1, either individually or in groups.
Research and Inquiry	1 hour	The teacher encourages students to research, especially noting that certain materials or salts can absorb more heat than others. They ask students to focus on methods of storing solar energy using these materials and concave mirrors. Emphasis is placed on the interdisciplinary importance of the topic. The teacher divides students into groups and assigns different tasks, encouraging them to fulfill their responsibilities diligently.	Students clarify their views on the problem situation and its solution through discussions within their created groups and inter-group discussions. They focus on understanding applications that can measure solar energy potential in their region and how they can be used. They learn how to measure the daily solar energy potential of their region using the Global Solar Atlas digital map. They then create graphs using applications and evaluate them among themselves.



		<p>To ensure that students understand the topic and problems well and have conducted sufficient research, the teacher asks various questions. These questions include: "What materials are important for storing solar energy?", "What is a solar energy mapping system and how is it digitally recorded?", "Can we measure the solar energy potential of our region?", "How should we use mirrors to store solar energy?", and "For what purpose and how is stored energy used?"</p> <p>This allows students to realize what they know and what they are lacking. The teacher directs students towards their own research by asking similar questions.</p> <p>Students are asked to write down the information they gather in Worksheet 2. Applications that can be used to measure solar energy potential are introduced, with particular emphasis on solar mapping systems.</p> <p>They are encouraged to conduct research and reach conclusions through discussions within their groups and among different groups.</p>	<p>They conduct research to increase their knowledge about materials with higher heat absorption capacities. They research and discuss how to utilize mirrors in heat collection and why certain types of mirrors are suitable for this purpose.</p> <p>They record the opinions that emerge through discussions among themselves and information exchange, either as group opinions or individually, in Worksheet 2.</p>
Designing and Creating a Product	1 hour	<p>The teacher encourages students to identify necessary materials and create designs. Working on different materials and designs in separate groups is encouraged. Applications are expected to be carried out and developed according to a specific strategy.</p> <p>During the solution generation phase, students are asked to determine which application/digital tool or similar tools they will</p>	<p>Students first identify the necessary materials and determine how they can acquire these materials and for what purposes they will use them. They also research which applications they can utilize to measure the solar energy potential in their region.</p> <p>They record the information they obtain and their research findings in Student Worksheet 3 by discussing their designs with each other and exchanging information.</p>

	<p>use to measure the effectiveness of their designs. During the prototyping and testing phase, students are asked to conduct preliminary trials and tests of the products they have designed.</p>	
<p>Product presentation, Discussion, and Evaluation</p>	<p>Students are encouraged to present their product outcomes in the form of reports and make future-oriented recommendations on solar energy storage; they are encouraged to identify the strengths and weaknesses of their products. The teacher may ask questions to guide discussions among students and those attending the presentations.</p> <ul style="list-style-type: none"> ● What parameters do you use in your solar energy storage studies? ● How do you plan to evaluate the results you have obtained? ● Do you have any future plans to improve your product? What could they be? ● What suggestions can you offer for the promotion and use of your product. 	<p>Students visualize the data they have collected using technological tools. They consider how the data will be analyzed and how the results will be presented. They can visualize the levels of generated or stored energy using graphs, tables, or maps. Then, they discuss with their peers and present reflections. They record the knowledge and skills they have gained during the work process in Student Worksheet 4.</p>



Student Worksheet 1: Solar Energy Storage Activity

Defining a problem

What contributions can harnessing solar energy make to the economy and the environment?

In which seasons and periods is solar energy more efficient? Why?

How can we harness the potential of solar energy?

Why is it important to store solar energy?

Are you aware of the methods used to store solar energy for later use? Discuss and write down what you know about this topic among yourselves.



Student Worksheet 2: Solar Energy Storage Activity

Recall and Research

- How can we understand the efficiency and potential of solar energy in our environment using digital maps?
- Do you know which materials have the property of heat absorption? How can we utilize these materials to store solar energy?
- Were you aware that mirrors are used to harness solar energy? What types of mirrors are used for this purpose?
- Are you familiar with the concept of 24/7 solar energy usage? What materials are used for what purposes in this context?
- What knowledge do you have on this subject? Identify and fill in your gaps accordingly.

Problem Definition

In the age we live in, the need for energy is increasing day by day and will continue to do so. Energy is obtained from various sources, but some of these sources harm the environment. Among them, solar energy is an infinite and clean energy source. Therefore, we need to make more use of it. The teacher demonstrates why solar energy is important among different energy sources with practical applications in their environment. They emphasize the importance of storing solar energy and provide opportunities for students to discuss and debate methods for storing solar energy for use during hours when the sun is not available. They particularly encourage research by pointing out that certain materials/salts can absorb heat more effectively than others. They instruct students to focus on how to store solar energy for later use using these materials and concave mirrors. They highlight the interdisciplinary importance of the topic. The teacher divides students into groups and assigns different tasks. They encourage students to make suggestions that will contribute to solving this problem.

R & Q

Research Question:

What would you like to know about various storage methods to harness solar energy more efficiently?

Research Planning:

Develop a strategy for your research.



Student Worksheet 3: Let's develop a system for storing solar energy 24/7

Designing and Creating Products

You will develop a system by storing solar energy and using various salt types as well as the main one in times when there is no sun. - What might you need for this system? Research and write.

Sketch/design such a system by discussing among yourselves / exchanging information. What materials do you need for what purpose? Specify on your design.

To test the efficiency of such a system, what electronic devices or applications might you need? Determine.

Research how you can utilize the heat you will obtain for what purposes.

Design Criteria:

The types of mirrors you will use and benefit from to monitor the efficiency of your solar energy storage product must be selected correctly.

The number and angles of the mirrors you decide on should be adjusted to provide the best performance.

Research the parameters needed to harness solar energy and test your product, create a table, and decide together how to use it.

The salts used to absorb solar energy in towers should have high heat retention capacities.

Your system design should be in portable sizes.

Your system should have an aesthetic appearance.

Model Creation:

Discuss among yourselves considering the criteria stated above.

Before making decisions, draw prototype models you have in mind and discuss the strengths and weaknesses of each.

Compile a list of necessary materials for the model you have decided on and write down why you need each material.

Determine the approach you will take when creating your model.

During the model creation process, be aware that a backup plan may be necessary if changes are needed.

Generate Solution-Design

Create graphs to evaluate the solar energy potential of your region according to seasons.

Determine your design by interpreting the graphs and data you have created.

Decide which design would be more appropriate.

Decide on the salts or mixtures you will use in your design.

Prototype Creation and Testing

Implement your design and test it. Evaluate the results.

Assess your success by discussing the strengths and weaknesses of the obtained result.



Product Introduction, Discussion, and Evaluation

Plan how you will introduce your product and inform relevant individuals, and prepare a presentation script. In the presentation text, emphasize why it is important how the planned salt tower works.

The products you plan and execute will be scored according to the following criteria.

Criterion
Are the selected mirrors suitable for the job the number sufficient?
The sizes of the mirrors are well chosen.
The salts/salt ratios selected for heat absorption are well planned.
The dimensions of the salt tower are suitable selected mirrors.
The produced system also creates a nice appearance from an aesthetic point of view
The system is capable of absorbing sufficient
The system exhibits portable characteristics be tested in various environments.
Total

Product Creation

When you tested the salt tower you produced, what deficiencies did you observe? If you were to remake it, what would you change? (Please write in detail or redraw your new draft.)



Student Worksheet 4: What I Learned

Reflection

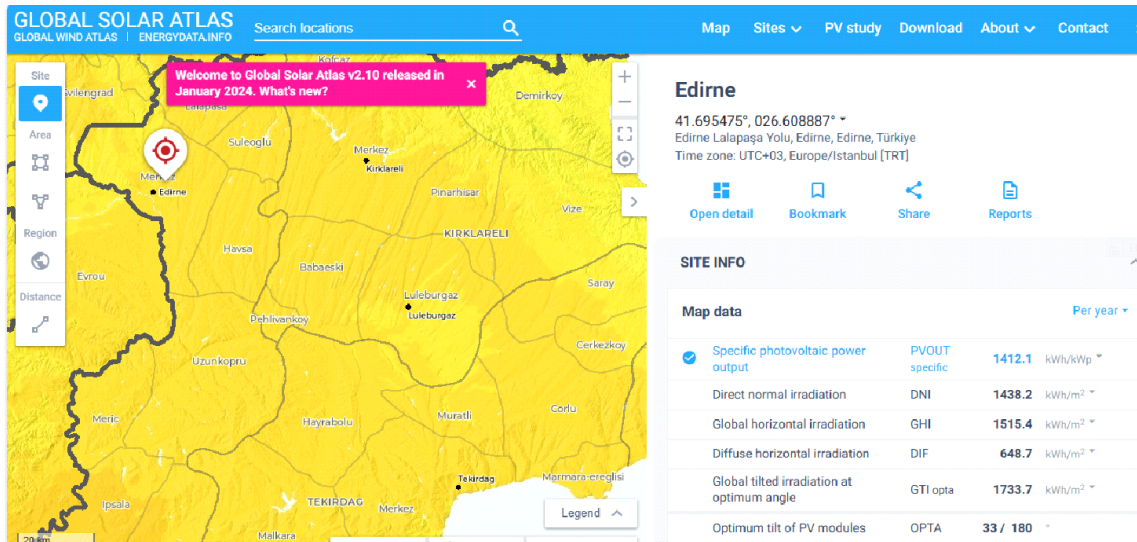
- What did you know at the beginning stage of this application?
- What did you learn during the research phase?
- Where and how did you acquire the information you obtained from your research?
- How did you overcome the challenges encountered while creating your model?
- What did you learn from evaluating the data obtained during the testing phase?
- Do you consider sharing the knowledge you gained here with your friends?
- Are you planning to continue working to improve your model after this study?
- Do you think your model will contribute to the environment on a large scale? Please explain why.



Digital Tool for Activity

The student measures the solar potential of their area using the following or similar links, employing different parameters.

<https://globalsolaratlas.info/map?c=41.374748,27.103271,9&s=41.695475,26.608887&m=site>



Teacher Note:

When planning the activity, divide students into groups with different skills and interests. Encourage collaboration among groups to allow them to develop teamwork skills.

Use the questions in the "Recalling Prior Knowledge and Experiences" section to help students recall what they already know and share their experiences. This will help students start the activity more prepared.

Encourage students to communicate with local authorities, environmental organizations, and experts to gather more information. This will make the activity more meaningful by providing students with insights into real-world problems.

Guide students to determine the necessary design criteria and create a material list. This will help students focus on the design process and achieve their goals.

Provide guidance to students on how to integrate GPS locators and map applications into their solar tower model. This will improve the monitoring process by enabling students to effectively use technology.

Give students the opportunity to test their mobile solar tower outside. Allow them to verify the accuracy of the data and evaluate the system's performance, providing them with real-world experience.

Enable students to prepare and present reports using the data they have obtained. This will help students develop presentation and evaluation skills, presenting their work like a scientist.



Description of innovative Green STEAM teaching/learning unit

Educational level (students' age): Middle School
Subject: Green STEM
Topics: Biomimicry Nanofabrics & Environmental Industry Practices
<p>Curriculum objectives:</p> <p>Science objectives:</p> <ul style="list-style-type: none"> • 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. <p>Engineering objectives:</p> <ul style="list-style-type: none"> • 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. <p>Technology objectives:</p> <ul style="list-style-type: none"> • 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. <p>Mathematics objectives:</p> <ul style="list-style-type: none"> • 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. <p>Art objectives:</p> <ul style="list-style-type: none"> • 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. <p>Related GREEN STEM objectives:</p> <ul style="list-style-type: none"> • GD2. Clean and Circular Economy

<ul style="list-style-type: none"> GD2.d. Innovative Practices for Sustainable Production and Reduction of Carbon Emissions and Greenhouse Gas Emissions in the Textile and Leather Sectors. 		
<p>Key words: Biometric concept, Lotus effect, Nano water repellency, Nano hydrophobic fabrics</p>		
<p>Learning tools:</p>	<p>Student worksheet 1, 2, 3</p>	<p>Wax, Vaseline, fabric wax, Superhydrophobic coating (Spray), Various fabrics, Test materials (such as plastic bottles, sponges, droppers, wooden sticks, measuring equipment, etc.)</p>
<p>Literature resources for students</p> <p>Arabacioglu, S. (2022). Can nanotechnology keep us dry in the rain: An inquiry-based activity to help students improve their investigation skills. <i>International Journal of Technology in Education and Science (IJTES)</i>, 6(3), 410-426. https://doi.org/10.46328/ijtes.395</p>		
<p>Literature resources for (future) teachers</p> <p>Arabacioglu, S. (2022). Can nanotechnology keep us dry in the rain: An inquiry-based activity to help students improve their investigation skills. <i>International Journal of Technology in Education and Science (IJTES)</i>, 6(3), 410-426. https://doi.org/10.46328/ijtes.395</p> <p>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. <i>International Journal of Science and Mathematics Education</i>, 14(3), 345–372. https://doi.org/10.1007/s10763-014-9579-0</p> <p>Ghattas, N. I., & Carver, J. S. (2012). Integrating nanotechnology into school education: A review of the literature. <i>Research in Science and Technological Education</i>, 30(3), 271–284. https://doi.org/10.1080/02635143.2012.732058</p> <p>Mandrikas, A., Michailidi, E., & Stavrou, D. (2020). Teaching nanotechnology in primary education. <i>Research in Science and Technological Education</i>, 38(4), 377–395. https://doi.org/10.1080/02635143.2019.1631783</p> <p>Sakhnini, S., & Blonder, R. (2016). Nanotechnology applications as a context for teaching the essential concepts of NST, <i>International Journal of Science Education</i>, 38(3), 521-538. https://doi.org/10.1080/09500693.2016.1152518</p>		
<p>Teaching method(s):</p>	<p>Problem-Based Learning, Inquiry-Based Learning, Project-Based Learning, Design Thinking and Engineering Design, Hands-on Science, Applied Learning, Technology-Enhanced Learning.</p>	

Scenario of Green STEAM teaching/learning unit

Phase	Required time	Teachers' activity	Students' activity
Recalling the Known	30 min	The teacher can start by grabbing students' attention and introducing the topic with an interesting question	Students can share what kind of experiences they have had in rainy weather and how water behaves



<p>and Experiences</p>		<p>or story. For example, they might ask students about the challenges they face on a rainy day or how they feel in the rain.</p> <p>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.</p> <p>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.</p> <p>Djital araç – Yağmurluklu bir insan görseli üzerinden tartışma....</p>	<p>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?</p> <p>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.</p>
<p>Research & Questions</p>	<p>1 hour</p>	<p>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 to closely examine the leaves under a magnifying glass and discuss the patterns or structures they observe.</p> <p>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.</p> <p>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</p>	<p>Students examine leaves obtained from the specified plant species under a magnifying glass. They take notes on the observed patterns or structures.</p> <p>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.</p> <p>They record their observations and experimental results on Worksheet 1.</p> <p>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</p>

		<p>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.</p>	<p>lotus leaves. They research if there are other plant examples in nature with water-repellent strategies.</p>
<p>Generate-Solution Design:</p>	<p>1 hour</p>	<p>Students are encouraged to brainstorm in groups to design their own nano-hydrophobic fabrics. Each group brainstorms by 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.</p>	<p>Students discuss examples to consider potential applications in everyday life. For instance, they are 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:</p> <ul style="list-style-type: none"> • 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.).



			<ul style="list-style-type: none"> • Creates simple prototypes of their products using environmentally friendly materials (such as wax, vaseline, paraffin, wax, superhydrophobic coatings, different fabrics (feather, parachute, upholstery), etc.).
<p>Prototype Creation and Testing:</p>	1 hour	<p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p>	<p>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 materials they used, and what results they obtained.</p> <p>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.</p>
<p>Product Introduction, Discussion, and Evaluation</p>	30 min	<p>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</p>	<p>Each student or group presents their own prototypes through a suitable Web 2.0 tool. They provide detailed information about the biomimicry principles used.</p>



	<p>encouraged to share on the following topics during the presentation:</p> <ul style="list-style-type: none">• Introducing the prototypes to the class and emphasizing the biomimicry principles used.• Presenting the test results and providing evidence of the effectiveness of each design.• Sharing the encountered challenges and lessons learned about water-repellent fabrics. <p>For evaluation purposes, students are expected to:</p> <ul style="list-style-type: none">• 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.	<p>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 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.</p>
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Worksheet 1: Let's Explore the Lotus Leaf

Recall and Research

Task

Take a close look at the given leaves. Observe their surface structure and how they behave on the water.

Surface Structure: Focus on the surface structure and pay attention to any unusual features or patterns you notice. Describe the texture of the leaf's surface. Is it smooth, rough, or somewhere in between?

Use a magnifying glass (if available) to examine the surface closely. Can you see small structures like bumps or waxy coatings?

What distinguishes the surface structure of the leaf you observed from other leaves?

Water Behavior: Take a dropper or a small container of water and carefully place a few drops onto the surface of the lotus leaf. Observe what happens to the water droplets. Draw the water droplets, showing their shapes and behaviors.

Describe how the water droplets interact with the leaf. Do they spread out or do they stay together in a specific arrangement?

Try gently tilting the leaf and observe what happens to the water droplets. Explain any interesting behaviors you observe.

Self-Cleaning: Have you ever heard of the term "self-cleaning"? Based on your observations, describe why the leaf might need to self-clean.

How can the unique surface structure of the leaf help it stay clean in its natural environment?



Worksheet 2: Water-Repellent Fabrics Inspired by the Lotus Effect

Problem definition



"The Lotus Effect" on Lotus Leaf Photo by Ravi Kant:
<https://www.pexels.com/photo/water-drop-on-green-leaf-5192286/>

The lotus plant (*Nelumbo nucifera*) is an aquatic plant that naturally grows in warm and temperate regions of Asia and Australia. This plant thrives in muddy or marshy waters found in ponds, rivers, and calm shallow streams. One of the extraordinary characteristics of the lotus plant is that its leaves and flowers are water-repellent, a phenomenon known as the "lotus effect." The lotus effect originates from special nano-sized structures on the surface of the plant. Thanks to these nanostructures, lotus leaves and flowers remain clean by repelling dirt with water. But is this feature unique to the lotus plant? No. When used in water-repellent clothing and textile products, the lotus effect ensures that water is less absorbed on the fabric's surface. This allows for faster drying of products and helps reduce water consumption during washing. Since the fabrics are more resistant to external influences, they can extend the lifespan of clothing and textile products. Producing long-lasting products translates to less production and waste. The aim of this activity is to develop innovative fabrics with lower environmental impacts, allowing for the use of materials with less environmental impact and reducing chemical usage, inspired by the lotus effect. Your task is to create a fabric that exhibits water repellency, drawing inspiration from the lotus effect.

Research & Questions

Problem Definition: Using the provided materials and tools, experiment with different fabrics and coatings to create your water-repellent fabric. Identify potential applications (e.g., raincoats, water-resistant bags, or self-cleaning surfaces). For this purpose, plan simple prototypes of the products you will create using materials such as wax, superhydrophobic coating, different fabrics, etc.

Materials and Tools Provided:

- Wax
- Superhydrophobic coating
- Various fabrics (cotton, polyester, nylon, etc.)
- Brushes and spatulas
- Water dropper
- Magnifying glass



Worksheet 3: Hydrophobic Fabric Prototypes & Testing

Product Design and Creation

Planning: Share tasks among group members, considering each individual's strengths and interests. Explain the method of applying hydrophobic coating or wax onto fabric.

Design Criteria:

- Focuses on reducing environmental impacts and adhering to sustainability principles in the selection and use of design materials.
- Designed for potential real-life applications (e.g., raincoats, waterproof bags, or self-cleaning surfaces, etc.).
- Creates simple prototypes of products using environmentally friendly materials (such as beeswax, petroleum jelly, paraffin, wax, super hydrophobic coating, various fabrics (down, parachute, upholstery), etc.).

Solution Generation-Design

Fabric Processing: Begin the process of treating the fabric with the selected hydrophobic coating or wax. Allocate time for application and drying periods, or expedite with a drying machine. Ensure that the process is evenly spread across the fabric surface and covers the entire fabric surface. Observe and discuss any changes in the surface properties of the fabric after processing.

Prototype Creation and Testing

Water Droplet Test: Place water droplets on the processed fabric using a pipette. Observe how water behaves on the surface of the fabric. Do the water droplets gather and roll off? Compare the water repellent behavior of the processed fabric with untreated fabric samples.



Assessment and Development:

Evaluate the effectiveness of your nano hydrophobic fabric prototype. Discuss any applications or improvements that could be made to increase its water repellency. Take into account the challenges encountered during the prototype process and explain potential enhancements.

Presentation: Prepare a brief presentation to share your prototype of nano hydrophobic fabric. Explain the basic features of your fabric, the inspiration you drew from the lotus effect, and potential real-life applications. Include your group's experiences throughout the process, the challenges faced, and what you have learned during the process in your presentation.

Note: Feel free to use additional pages for drawings, photographs, notes, and any extra information you'd like to add to your presentation. Some presentation tools you can use include: Prezi, Google Slides, Canva, Powtoon, Emaze, Storyboard, etc.



Teacher's Note:

This activity focuses on introducing students to water-repellent fabrics and the concept of biomimicry through a series of sub-activities. In the first activity, students will explore the importance of water-repellent fabrics with real-life examples. By observing the lotus effect, they delve deeper into this concept by observing water droplets forming and sliding off the surface of lotus leaves. In the second activity, students will learn about the principles of the lotus effect and its application in nano hydrophobic fabrics. The third activity encourages students to develop innovative design ideas for nano hydrophobic fabrics. At this stage, students will translate their ideas into tangible fabric prototypes using various materials and tools. They will have the opportunity to evaluate their designed prototypes through water tests.

Throughout this process, students will:

- Understand water-repellent fabrics and the concept of biomimicry,
- Learn how the "lotus effect" inspires the design of nano hydrophobic fabrics,
- Grasp key features such as micro/nano structures and low surface energy that make the lotus leaf surface impermeable to water.

The activity is particularly focused on introducing students to water-repellent fabrics and biomimicry, with an emphasis on the "lotus effect." The lotus effect is a phenomenon observed in nature, inspired by the surface of lotus leaves, where water droplets roll off, leaving it clean and dry. This unique property arises from micro/nano structures on the leaf's surface and its low surface energy, making it highly resistant to water. Additionally, biomimicry, the practice of solving human problems by taking inspiration from nature, is a highly relevant and significant concept for Green STEM education.

Green STEM education aims to promote an understanding of ecological principles and the importance of sustainability. Biomimicry aligns perfectly with these goals by encouraging students to think creatively and innovatively by seeking solutions from the natural world. Biomimicry draws upon various scientific disciplines such as biology, chemistry, physics, and engineering. By integrating biomimicry into Green STEM education, students engage in interdisciplinary learning. Biomimicry provides concrete examples of how sustainable solutions can be integrated into technology and industry, thus enabling products, buildings, and systems to be environmentally friendly and energy-efficient.

This STEM activity is organized with a plan that includes understanding concepts, defining, brainstorming ideas, designing prototypes, and testing them, allowing for a deep understanding of environmental issues, the development of innovative solutions, and the improvement of ideas through testing and feedback. The understanding concepts stage helps participants establish an emotional connection with the topic and gain a sense of new understanding and motivation to learn. During the defining stage, participants analyze the data they have gathered and identify the root causes of the environmental issue they want to address. A well-defined problem statement forms the basis for an effective and targeted solution. In the next stage, participants brainstorm to generate green and sustainable ideas. After generating many ideas, participants select the most feasible solutions and begin the design/prototype phase. This stage involves creating prototypes or detailed plans for green STEM solutions. Participants may use various tools, software, or materials to develop their designs. In the testing stage, participants subject their prototypes to evaluation to assess their effectiveness and identify areas for improvement. Depending on the nature of the projects, simulations, experiments, or real-world tests may be conducted. The testing stage provides valuable



feedback for participants to refine their designs and make them more effective and environmentally friendly.

Concepts, Terms:

Water Repellency: Water repellency is defined as the ability of a material or surface to resist the penetration or adhesion of water. When something is water repellent, water droplets typically bead up on the surface and do not get absorbed or wetted. This property is also known as hydrophobicity and is often observed in materials with low attraction to water.

Lotus Effect: The Lotus Effect is characterized by the ability of lotus leaves to repel water and effectively self-clean. When water comes into contact with a lotus leaf, it forms small spherical droplets instead of spreading out on the surface, making it easy to roll off. These droplets collect dirt, dust, and other pollutants, leaving the leaf clean.

Hydrophobic Fabric: Hydrophobic fabric refers to a type of textile or material that repels water and resists wetting. Hydrophobic fabrics are typically processed or designed to have low surface energy, causing water droplets to bead up and roll off the surface.

Low Surface Energy: Low surface energy is a property where a material or substance has minimal ability to adhere to other materials. In other words, materials with low surface energy make it difficult for liquids and solids to wet or adhere to them. This property arises from the surface structure and chemical composition of the material.

Superhydrophobic Coating: A superhydrophobic coating refers to a special type of coating or treatment applied or processed onto a surface that exhibits extremely high resistance to water or other liquids. In simple terms, it is a coating that renders the surface highly resistant to water or other liquids, causing droplets to form nearly perfect spherical shapes and easily roll off the surface.

Principles, Theories: Biomimetic Principles: Biomimicry is an application used to solve human challenges and create innovative solutions by mimicking biological processes, systems, and patterns found in living organisms.

Principles of Sustainable Development: Principles of sustainable development emphasize balancing various interactions for the sustainable use and conservation of water resources.



Example: Environmental monitoring tools Meriç River Water Quality

Description of innovative Green STEAM teaching/learning unit

Educational level (students' age): Middle School
Subject: Green STEM
Topics: Environmental monitoring tools Meriç River Water Quality
Curriculum objectives: Science Achievements: <ul style="list-style-type: none">• Understands chemical and biological factors in the process of collecting and analyzing water samples (Comprehension).• Applies basic principles of science to determine water quality (Application).• Evaluates the living conditions of organisms in the ecosystem (Evaluation). Associated Green Deal Strategies: <ul style="list-style-type: none">• GD1. Climate Change, Environment, and Biodiversity: Aim to Regulate Climate Change, Carbon Emissions, and Greenhouse Gas Emissions.• GD1.c. Remote Sensing and Information Technology Applications in Water Resources Management. Engineering Achievements: <ul style="list-style-type: none">• Utilizes engineering principles in designing and developing a water quality monitoring system.• Integrates GPS locators and processes data onto maps.• Adapts to data collection and analysis processes using water analysis kits and other tools. Technology Achievements: <ul style="list-style-type: none">• Integrates data collection and mapping processes using mobile applications.• Measures water quality values using sensor technologies.• Understands the importance of digital technologies in ensuring data security and integrity. Mathematics Achievements: <ul style="list-style-type: none">• Evaluates collected data with basic statistical analyses.• Represents changes over time using graphs.• Conducts map analyses using coordinate systems. Art Achievements:



- Designs monitoring systems aesthetically using visual design skills.
- Presents collected data with an artistic approach (e.g., infographics, graphs).

Key words:

Water Pollution, Ecosystem, Biological Diversity, pH Level, Oxygen Amount, GPS Location Determiner, Water Analysis Kits, Monitoring System, River Map

Learning tools:

Worksheet 1, 2
https://content.e-me4all.eu/wp-admin/admin-ajax.php?action=h5p_embed&id=10525
https://content.e-me4all.eu/wp-admin/admin-ajax.php?action=h5p_embed&id=10507

Digital tools, maps, GPS locators, water analysis kits, water sampling equipment, etc.

Literature resources for students

Arabacioglu, S., & Unver, A. O. (2016). *Supporting inquiry-based laboratory practices with mobile learning to enhance students' process skills in science education. Journal of Baltic Science Education, 15(2), 216.*

Literature resources for (future) teachers

Arabacioglu, S., & Unver, A. O. (2016). *Supporting inquiry-based laboratory practices with mobile learning to enhance students' process skills in science education. Journal of Baltic Science Education, 15(2), 216.*

Situmorang, M., Sinaga, M., Purba, J., Daulay, S. I., Simorangkir, M., Sitorus, M., & Sudrajat, A. (2018). *Implementation of innovative chemistry learning material with guided tasks to improve students' competence. Journal of Baltic Science Education, 17(4), 535.*

Krauss, Z., Kline, D., Marcum-Dietrich, N.I., Stunkard C., Kerlin, S. & Staudt, C. (2022). *Protecting our WATERS: A 5E lesson sequence derived from a National Science Foundation-funded middle school watershed sustainability curriculum. Science Activities, (59)2, 97-105. DOI: 10.1080/00368121.2022.2063243*

Kim, H. (2011). *Inquiry-based science and technology enrichment program: Green earth enhanced with inquiry and technology. Journal of Science Education and Technology, 20, 803-814.*

Hite, R. H. & White, J. (2019). *Balancing profits and conservation: a human environmental impact PBL for upper elementary and middle grades STEM club students. Science Activities, (56)3, 88-107. DOI: 10.1080/00368121.2019.1693950*

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
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<p>Defining problem</p>	<p>30 min</p>	<p>Activity focused on monitoring water quality in the Meriç River (English: Maritsa or Maritza, Bulgarian: Марица, Greek: Έβρος) can be implemented by teachers in various regions and adapted to local natural water sources. This enables understanding and addressing water pollution issues in various geographical areas. For the activity, students are divided into appropriate groups, and each is assigned specific tasks or responsibilities. Collaboration among groups is encouraged.</p> <p>The aim of the activity is for students to understand the summarized problem situation and to encourage them to think about the questions under the subheading "Recalling What is Known and Experienced" in Student Worksheet 1 to reinforce their experiences.</p> <p>https://content.e-me4all.eu/wp-admin/admin-ajax.php?action=h5p_embed&id=10507</p>	<p>Students analyze, define, and discuss the issue regarding monitoring the water quality in the Meriç River (English: Maritsa or Maritza, Bulgarian: Марица, Greek: Έβρος) with their peers. What is known about the problem situation and emerging views are recorded on Student Worksheet 1 either as a group or individually.</p> <p>https://content.e-me4all.eu/wp-admin/admin-ajax.php?action=h5p_embed&id=10507</p>
<p>Recalling and Research</p>	<p>1 hour</p>	<p>In the "Areas to Investigate" section, students are encouraged to think about which questions they want to answer regarding water pollution in the Meriç River. For example, they are aimed to develop researchable questions such as "How does water quality change?" "In which areas is pollution more prevalent?" "How does water quality change over time in a specific region?"</p> <p>Students are supported in planning appropriate methods for their research questions. They are introduced to (https://content.e-me4all.eu/wp-admin/admin-ajax.php?action=h5p_embed&id=10525) they can use in this process. They are asked to research and discuss details such as how to collect water samples, how to conduct analyses, and how to record data, and record them on Student Worksheet 2 by discussing with their peers.</p>	<p>The student conducts research on the problem situation, clearly defines the research questions, and plans a research method that can answer the research questions by working on:</p> <p>https://content.e-me4all.eu/wp-admin/admin-ajax.php?action=h5p_embed&id=10525</p> <p>What is known about the research plans and emerging opinions are recorded in Student Worksheet 1, either through group discussion or individually.</p>
		<p>In the Product Design and Development phase, students are encouraged to identify the materials they will need in</p>	<p>Students design the water monitoring protocol they will develop over time to monitor water pollution in</p>



<p>Designing and Creating Product</p>	<p>designing a sustainable protocol for monitoring water pollution. They are asked to make a list of tools they may need, such as Maps, GPS locators, water analysis kits, and water sampling equipment. They are encouraged to progress through the criteria in the Design Criteria section during this process.</p> <p>Under the Solution Generation-Design heading, students are directed to create a protocol for monitoring pollution levels in specific areas of the river. This protocol should detail where, how often, and which parameters will be measured. Additionally, they are asked to plan which technologies they will use during the monitoring process. They are encouraged to consider how to integrate technological tools such as GPS locators, map applications, and water analysis devices.</p> <p>For Prototype Creation and Testing, students are guided to brainstorm ways to describe the river water monitoring protocol they have designed. With the help of experts, students are taken on a field trip to a riverbank to test their designed protocol in the field. They are asked to verify the accuracy of the data and evaluate the performance of the system.</p> <p>When selecting areas, attention is paid to the areas before and after the industrial zones</p>	<p>the Meriç River within the framework of design criteria.</p> <p>Design criteria for the water monitoring system to monitor water pollution levels in the Meriç River over time:</p> <ul style="list-style-type: none"> → The system should be able to measure various properties of water (pH levels, oxygen levels, temperature, pollutants, etc.) with high sensitivity. → The system should be able to monitor pollution levels in specific areas along the river. → Enhance field data collection efforts by integrating GPS locators like mobile phones. → Take into account budget constraints and the materials supplied. <p>The protocol they will create to monitor pollution levels is recorded in Student Worksheet 2. They answer research questions and create a list of materials needed for designing the water monitoring protocol. Among these materials may be water sampling bottles, pH meters, oxygen sensors, thermometers, and various water analysis kits. GPS locators, mobile phones, or specialized GPS devices can be used to process data on a map.</p> <p>They develop a protocol to monitor pollution levels in specific areas of the river. This protocol determines which areas, how often, and which parameters will be measured. They plan how to use technological tools during the monitoring process, such as GPS locators, map applications, and water analysis devices.</p>
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			<p>They actively participate in field trips and record their data. They collect water samples at intervals consistent with their protocol in designated areas. They visualize changes by marking collected data. They analyze collected water samples, measuring parameters such as pH levels, oxygen levels, temperature, and pollutants.</p>
<p>Product Presentation, Discussion, and Evaluation</p>		<p>Students are encouraged to prepare a report containing the results from the monitoring protocol they have developed for Product Introduction, Discussion, and Evaluation, and to make recommendations regarding water quality in the river in this report. They are encouraged to suggest improvements to their protocols based on the results obtained.</p> <p>The discussions may be accompanied by the following questions:</p> <ul style="list-style-type: none"> → Why did you decide to conduct this research to evaluate the effects of water pollution in the Meriç River on its natural beauty and species? → Which parameters did you examine to evaluate the water quality in the river? What could be the effects of these parameters on the river ecosystem? → How might the results of this research affect the river ecosystem, and what measures might need to be taken based on these results? → What can society and local governments do to raise awareness about water pollution in the Meriç River and address this issue? → What kind of improvements can be made if one wishes to develop the product designed to evaluate the water quality in the river? 	<p>Students visualize the data they collect with technological support. They contemplate how to analyze the collected data and how to present the results. They can visualize pollution levels using graphics, tables, or maps. They discuss with their peers and present reflections.</p>



Student Worksheet 1: Monitoring River Water Pollution

Recall and Research

Why are river ecosystems important? Explain.

What is Water Pollution? What could be the main pollutants? Explain.

Problem Definition

The Meriç River, famous for its natural beauty throughout history, has been home to many species of wildlife. However, recently, there have been reports of a significant decrease in water quality in certain areas. This indicates that there are changes in the river ecosystem causing adverse effects and putting the lives of organisms at risk. The Underwater Detectives team was established to investigate water pollution in the Meriç River. Young scientists have decided to use various scientific methods to examine changes in the river and identify their sources. Within this scope, processes such as collecting water samples, monitoring the pH levels, oxygen levels, temperature, and various pollutants in the water will be carried out. Additionally, goals have been set to mark the data collected from the field on a map to monitor pollution levels in specific areas of the river. The Underwater Detectives team requests that you develop a monitoring system to understand how pollution in the Meriç River changes over time. In this process, materials such as river maps, GPS locators on cell phones, and various water analysis kits will be used. Along with the materials provided by the underwater detectives, the aim is to create an effective monitoring system to find a solution to the problem of water pollution in the Meriç River.

Research

R&Q:

What questions would you like to answer regarding water pollution in the Meriç River? Write down the questions you want to investigate.

Research Planning:

Please briefly outline the research you can conduct regarding your research problem. (Consider details such as how water samples will be collected, how analyses will be conducted, how data will be recorded, etc.)



Student Worksheet 2: Designing a Water Pollution Monitoring Protocol

Design and Create Solution	
<ul style="list-style-type: none"> → You will design a sustainable protocol for the water pollution monitoring system. → Consider what materials you will need. (Digital tools, maps, GPS locators, water analysis kits, water sampling equipment, etc.) https://content.e-me4all.eu/wp-admin/admin-ajax.php?action=h5p_embed&id=10525 → Begin listing your materials, taking into account design criteria. 	<p>Design Criteria</p> <p>Design criteria for the water monitoring system you will develop to track the water pollution in the Meriç River over time:</p> <ul style="list-style-type: none"> → Protocol to measure various properties of the water (pH levels, oxygen levels, temperature, pollutants, etc.) with high precision. → Protocol should be able to monitor pollution levels in specific areas along the river. → Enhancing field data collection efforts by integrating GPS locators like those found in mobile phones. → Considering budget constraints and available materials in procurement.

Prototype
<ul style="list-style-type: none"> → Create a protocol to monitor water pollution levels in specific regions. → Detail which areas, how frequently, and which parameters will be measured in your protocol. → Plan which technologies you will use during the monitoring process. (GPS locators, mapping applications, water analysis devices, etc.)

Prototype Testing
<ul style="list-style-type: none"> → Define the river water monitoring protocol you designed by brainstorming. → Arrange a field trip to test your protocol in the field. → Check the accuracy of the data and evaluate the performance of the system. → Review the protocol you designed to monitor water pollution in the Meriç River over time and check its compliance with design criteria.

Info:



Co-funded by
the European Union



Record the protocol you have created for monitoring pollution levels on this worksheet. Participate in field trips, record data using https://content.e-me4all.eu/wp-admin/admin-ajax.php?action=h5p_embed&id=10525 and test your protocol.



Digital Tools for Activity

Interactive video:

Introduction to Water Sampling

Link:

https://content.e-me4all.eu/wp-admin/admin-ajax.php?action=h5p_embed&id=10525

Insites:

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<iframe src="https://content.e-me4all.eu/wp-admin/admin-ajax.php?action=h5p_embed&id=10525" width="800" height="600" frameborder="0" allowfullscreen="allowfullscreen"></iframe><script src="https://content.e-me4all.eu/wp-content/plugins/h5p/h5p-php-library/js/h5p-resizer.js" charset="UTF-8"></script>
```

Image Hotspots:

Organize your field trip and record your data

Link:

https://content.e-me4all.eu/wp-admin/admin-ajax.php?action=h5p_embed&id=10507

Insites:

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<iframe src="https://content.e-me4all.eu/wp-admin/admin-ajax.php?action=h5p_embed&id=10507" width="800" height="600" frameborder="0" allowfullscreen="allowfullscreen"></iframe><script src="https://content.e-me4all.eu/wp-content/plugins/h5p/h5p-php-library/js/h5p-resizer.js" charset="UTF-8"></script>
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Teacher Note:

→ When planning the activity, divide students into groups with different skills and interests. Encourage collaboration among groups to allow them to develop teamwork skills.

→ Use the questions in the "Recalling Knowns and Experiences" section to help students recall previously learned information and share their experiences. This will help students start the activity more prepared.

→ Encourage students to communicate with local authorities, environmental organizations, and experts to gather more information about water pollution in the Meriç River. This will make the activity more meaningful by enabling students to learn about real-world problems.

→ Guide students to determine the design criteria necessary for the water monitoring system and to create a list of materials needed. This will help students focus on the design process and achieve their goals. Use the information cards below for analysis parameters identified by students in the testing protocol.

→ Provide guidance to students on how to integrate technological tools such as GPS locators, map applications, and water analysis devices into their planning. This will enhance the monitoring process by enabling students to use technology effectively.

→ Allow students the opportunity to field-test the prototype of the water monitoring system they have designed. Enable them to check the accuracy of the data and evaluate the system's performance, providing them with real-world experience.

→ Ensure that students prepare a report containing the results of the monitoring system they have developed and present recommendations regarding pollution in the river. This will help students improve their presentation and evaluation skills.

→ Consider the necessary time and sequencing of activities when planning the activity. Ensure that students have sufficient time at each step and create a timeline to facilitate the flow of the activity.



Innovative Green STEAM teaching/learning unit

Educational level (students' age): Middle - High School (10-16 years old)
Konu Alanı: Green STEM
Subject: Green Agriculture and Industrial Products: Pectins from Sunflower Head
<p>Curriculum objectives:</p> <p>Science Achievements:</p> <ul style="list-style-type: none"> ● Selects and applies the appropriate method that can be used to separate the mixtures. ● Selects between recyclable or non-recyclable substances in waste. ● Offers solution suggestions using research data on the contribution of recycling to the country's economy. ● Creates or revises scientific explanations based on valid and reliable data or evidence obtained from sources (including own experiments). ● Uses valid and reliable data or evidence from a different of sources (including own research, experiments, peer reviews, etc.) to support or evaluate the statement or conclusion. <p>Engineering Achievements:</p> <ul style="list-style-type: none"> ● Understands that engineers work to improve existing technologies (increasing their benefits or reducing known risks) or developing new ones to meet societal demands/needs. ● Applies the engineering design cycle. ● Takes into consider the criteria and constraints of the design problem to achieve a successful solution. ● Combines the best features of each item or solution by analyzing the similarities and differences between various design solutions for a new solution to provide measures of success. <p>Technology Achievements:</p> <ul style="list-style-type: none"> ● Explains the factors affecting the development of technology. ● Explains how technological developments affect societies and individuals. ● Evaluates opportunities for recycling finished products. ● Evaluates opportunities for recycling finished products. <p>Mathematics Achievements:</p> <ul style="list-style-type: none"> ● Collects data regarding the solution of real/realistic life problems. ● Records data regarding the problem situation and/or solution using an appropriate representation method (table, graph, etc.).



- Applies mathematical concepts and/or processes (e.g. ratio, proportion, percentage, basic operations, unit conversions, etc.) in the context of a scientific and/or engineering problem
- Understands the importance of repetition of experiment or measurement in experimental studies.

Entrepreneurship Achievements:

- Identifies social needs and produces innovative ideas to meet them.
- Uses mass communication channels to promote the product they have developed.
- Expresses and discusses her/his ideas and findings clearly and consistently to a professional audience using visual, written and orally communication methods.

Green STEM Achievements:

- 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.

Associated Green Deal Strategies:

- Sustainable Industry

Nature of STEM / Career:

- Assuming herself/himself as a team member in different roles in the project work, she/he combines 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 ensure success criteria.
- In a proje, she/he assumes herself/himself as a team member in different roles and successfully completes the work required by that role (notices the importance of interdisciplinary work).
- Notice aware of basic science, technology and engineering disciplines and career opportunities in these fields.
- Researches the study of different disciplines and have knowledge about current and interdisciplinary professions.

21. Century Skills Achievements:

- Improves problem solving skills
- Improves collaborative working skills (understands that many scientists and engineers work collaboratively in teams).
- Her/He sensitivity to the environment and the world she/he lives in increases.

Theoretical Knowledge:

Pectic substances are a family of natural polysaccharides found in the cell walls of all plants and fruit peels, and are used in the food industry as gelling, thickening, emulsifying and stabilizing agents. Pectin is widely used in the production of jam, marmalade, jelly, fruit juices, dairy products, sauces, tomato paste, mayonnaise and bakery products, especially due to its ability to gel with sugar. The main countries producing pectin in the world are Mexico, Brazil, China, Switzerland, USA, Argentina and Italy. Türkiye imports pectic substances needed by the food industry. According to TUIK (Turkish Statistical Institute) data, the pectic substances import of Türkiye



during 2022 are 739 tons, and its value is about 8.1 million dollars. Türkiye is an agricultural country. The fruit pulps, which becomes waste especially in the citrus and other fruit processing sectors, into product is important in terms of sustainability and recycling in agriculture. Fruit pulps from agricultural organic waste and also industrial wastes can be used for pectin isolation. One of the most grown agricultural product in the Thrace region is sunflower, and the head of the sunflower remains in the field after harvest. This agricultural waste material can be converted into a commercial product with high added value and thus contribute to the economy.

Key words: Agricultural organic waste, pectin, gelling, food additive, entrepreneurship, natural product, recycling, sustainability.

Learning tools:

Worksheets
Flashcards

Equipment's and Material:

Sunflower heads from the field after harvest, ammonium oxalate-oxalic acid mixture, acidified alcohol (Ethanol + HCl), commercial pectin from the market for comparison, heater, precision scale, cheesecloth, cotton wool, beaker glass, erlenmeyer, glass rod, funnel, measuring cylinder etc. glass materials.

Literature Resources For Students

Kaya M, Sousa AG, Crépeau MJ, Sørensen SO, Ralet MC. (2014). Characterization of citrus pectin samples extracted under different conditions: Influence of acid type and pH of extraction. *Annals of Botany*, 114(6):1319-26. doi: 10.1093/aob/mcu150.

Ma, X., Yu, J., Jing, J., Zhao, Q., Ren, L., Hu, Z. (2021). Optimization of sunflower head pectin extraction by ammonium oxalate and the effect of drying conditions on properties. *Scientific Reports*, 11, 10616. <https://doi.org/10.1038/s41598-021-89886-x>

Peng, X., Yang, G., Shi, Y., Zhou, Y., Zhang, M., Li, S. (2020) Box–Behnken design based statistical modeling for the extraction and physicochemical properties of pectin from sunflower heads and the comparison with commercial low-methoxyl pectin. *Scientific Reports*, 10, 3595. <https://doi.org/10.1038/s41598-020-60339-1>

Venkatanagaraju, E., Bharathi, N., Hema Sindhuja, R., Roy Chowdhury, R., & Sreelekha, Y. (2020). Extraction and purification of pectin from agro-industrial wastes. *IntechOpen*. doi: 10.5772/intechopen.85585

Chandel, V.; Biswas, D.; Roy, S.; Vaidya, D.; Verma, A.; Gupta, A. (2022). Current advancements in pectin: Extraction, properties and multifunctional applications. *Foods*, 11, 2683. <https://doi.org/10.3390/foods11172683>

Literature Resources For (Future) Teachers

Kaya M, Sousa AG, Crépeau MJ, Sørensen SO, Ralet MC. (2014). Characterization of citrus pectin samples extracted under different conditions: Influence of acid type and pH of extraction. *Annals of Botany*, 114(6):1319-26. doi: 10.1093/aob/mcu150.

Ma, X., Yu, J., Jing, J., Zhao, Q., Ren, L., Hu, Z. (2021). Optimization of sunflower head pectin extraction by ammonium oxalate and the effect of drying conditions on properties. *Scientific Reports*, 11, 10616. <https://doi.org/10.1038/s41598-021-89886-x>

Peng, X., Yang, G., Shi, Y., Zhou, Y., Zhang, M., Li, S. (2020) Box–Behnken design based statistical modeling for the extraction and physicochemical properties of pectin from sunflower heads and the comparison with commercial low-methoxyl pectin. *Scientific Reports*, 10, 3595. <https://doi.org/10.1038/s41598-020-60339-1>



Venkatanagaraju, E., Bharathi, N., Hema Sindhuja, R., Roy Chowdhury, R., & Sreelekha, Y. (2020). Extraction and purification of pectin from agro-industrial wastes. IntechOpen. doi: 10.5772/intechopen.85585

Chandel, V.; Biswas, D.; Roy, S.; Vaidya, D.; Verma, A.; Gupta, A. (2022). Current advancements in pectin: Extraction, properties and multifunctional applications. Foods, 11, 2683. <https://doi.org/10.3390/foods11172683>

Below links are news about studies on pectin production in our country and it is recommended to read.

1) <https://mam.tubitak.gov.tr/tr/haber/gida-sanayimiz-icin-yerli-ve-dogal-pektin-uretecegiz>

2) <https://www.aa.com.tr/tr/ekonomi/sakaryada-atik-ayvadan-pektin-seluloz-ve-hemiseluloz-uretiliyor/3001060>

3) <https://www.yatirimadestek.gov.tr/pdf/assets/upload/fizibiliteler/karaman-ili-pektin-uretim-tesisi-on-fizibilite-calismasi-2021.pdf>

Teaching method(s):

Project-Based STEM Approach, Problem-Based Learning, Inquiry-Based Learning, Project-Based Learning, Applied Learning (Hands-on Science)

Scenario of Green STEAM teaching/learning unit: Pectins from Sunflower Head

Phase	Required time	Teachers' activity	Students' activity
Defining problem	30 min	<p>A visual presentation should also make while informing the students about the problem. Students are encouraged to read, analyse and discuss the problem situation. At this stage, it is aimed to increase students' awareness about recycling and to create the idea that they can use the resources they have well and functionally.</p> <p>The groups should be formed equally and homogeneously.</p>	<p>Students analyse and discuss the problem situation presented in the worksheet and explained by their teachers. They define the problem and write what is requested of them in the relevant section of Student Worksheet 1.</p> <p>Students in each group determine their duties and responsibilities and record them in the relevant section of Student Worksheet 1.</p>



		Makes the necessary explanations about the Student Worksheets to be filled in during the activity.	
Recalling and Research	1 hour	<p>In order to reveal their prior knowledge about the problem situation, students are asked to answer the questions they know in the Recalling What is Known and Experienced section of Student Worksheet 1. During this process, they may be writing and answer other questions that they mind.</p> <p>At the Areas to Investigate section, students are encouraged to think about finding a solution to the problem within the framework of the questions in the relevant section of Student Worksheet 1. Here, students are asked to research and write answers to questions about pectic substances, and especially their intended use in the food industry. It is recommended that the teacher ask guiding questions or make explanations about the terms gelling, viscosity and agricultural waste. They are also allowed to brainstorm on topics such as recycling waste, sustainability economy and agriculture. They answer to new questions during this period, if any.</p> <p>Students are reminded to cite written or web sources they used during their research.</p>	<p>The students make investigation on the problem situation. What is known about the research and the resulting opinions are recorded as the group opinion or individually in Student Worksheet 1.</p> <p>In order to find a solution to the problem, students brainstorm within the group and generate questions regarding the information. They answer to the questions asked by the teacher, if any.</p> <p>Students indicate the written or web resources they used during their research.</p> <p>Students write the answers to the questions in the Areas to Investigate part in the Recalling and Research section of Worksheet 1. They also write the answers to the questions asked by their teachers during their brainstorming in this section.</p>
		In the Design and Create Solution section, the features and limitations of the product	



Designing Product	2 hours	<p>are given to students in Student Worksheet 2.</p> <p>The limitations of the study on pectin isolation are as follows.</p> <ul style="list-style-type: none">• Sunflower head should be used to obtain the product.• The product must be obtained in solid form.• The product must be odorless.• The viscosity of the jam made with the pectin obtained should be close to that of the jam made with commercial pectin.• Experimental procedures to be used to obtain the product must be suitable for use in the home environment. <p>During the Designing Product, students should be made aware that there may be different sources that can be used to obtain pectin, various experimental methods may be available, and therefore there may be more than one option as a solution. However, at this stage, students should be guided to make their choices within the given limitations.</p> <p>After students decide which method they will use, they may be asked to explain the reasons for their choice. They should write the list of experimental materials they will use and the experiment procedure they decided in the Design and Create Solution section of Student Worksheet 2.</p>	<p>Students make their final decisions among the various solutions within the design criteria and by presenting their reasons.</p> <p>They determine the materials necessary for the experiment of the chosen method.</p> <p>Students list the materials, tools and equipment they will use as a result of their decision. By clarifying the details of their experimental plans, they draw the experimental processes in full detail, such as flow charts, experimental procedures etc., or write it clearly if necessary. They fill out the Design and Create Solution section in Student Worksheet 2.</p> <p>They start apply their plans after presenting their plans to their teachers and receiving approval.</p>
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		The materials required for the activity should be prepared in advance.	
Creating Product and Testing	4 hours	<p>In the Creating Product and Testing phase, students are guided to apply their plans and obtain products using the appropriate materials of their choice. They are asked to perform the tests in the Creating Product and Testing section in Student Worksheet 2 on the product they obtain.</p> <p>The Creating Product phase offers students the opportunity to implement the design process they have planned.</p> <p>In the Testing and Data Recording phase: Determines which features data needs to be collected to test the product and presents a data table to the students. Might allow students to brainstorm in groups about what other tests they could do on their products. Students perform the tests in the Creating Product and Testing section in Student Worksheet 2 on the product they obtain. It is asks students to evaluate the data of the tests and record them in the relevant section of Student Worksheet 2.</p>	<p>They perform their plans exactly.</p> <p>Record the data and observation results they obtained as a result of the application in the Creating Product and Testing section in Student Worksheet 2.</p> <p>If they want to run further tests on their products, they can add the new data tested.</p>
		In the Product Evaluation phase: According to the rubric given in Student Worksheet 2 , students are asked to evaluate whether their products are successful or not, according to the given criteria, within their own groups. It allows them to save their results and comments in the relevant section.	According to the evaluation rubric presented by the teacher, based on the data obtained, they discuss it in the group and evaluate whether their products are successful or not. They fill out the rubric in Student Worksheet 2 . All groups calculate the total score of their products and compare their results and comment with their teacher.



Product Evaluation and Developing	30 min	<p>In the Product Evaluation and Development phase: Various questions can be asked to students. For example:</p> <ul style="list-style-type: none"> -Are there any difficulties in the experimental part of the study? -Are the efficiency and features of your products good? -Are there any changes you plan to make to your product? -What other natural and/or waste products can be used to obtain pectin? 	<p>In order to improve the product, changes that can be made to the product are discussed and planned in the group.</p>
	1 hour	<ul style="list-style-type: none"> -Can natural products be used for this purpose instead of the ammonium oxalate-oxalic acid mixture used to make the solution acidic? -What natural products can you use to make the solution acidic? <p>They can be asked to brainstorm what they can do to improve their product.</p> <p>Students are asked to discuss among themselves the changes they plan to improve the product and record them in the relevant section of Student Worksheet 2.</p> <p>One of the most grown plants in the Thrace region is sunflower, and sunflower heads remain in the field as natural waste. Natural waste products, from which pectic substances can be obtained, can be modified depending on the region. For example, in regions where quince or pomegranate cultivation is abundant, wastes such as peel</p>	



		<p>and pulp remaining after processing quince or pomegranate fruits can be evaluated. In this regard, the teacher can create ideas in students about the recycling of agricultural waste and sustainability.</p> <p>If students want to continue experimental processes with different fruit and vegetable wastes, they can be encouraged to develop their projects.</p>	
<p>Product Presentation and Discussion</p>	<p>1 hour</p>	<p>Gives students the opportunity to present their designs. Each group is allowed to prepare a presentation using technology. Their participation can be ensured by creating a scenario to develop entrepreneurial skills (for example, preparing a project for apply to the Thrace Development Agency, preparing a project for priority areas of TÜBİTAK such as environmentally sensitive or High Added Value Green Competitive Production).</p> <p>At the stage of Product Presentation, They are guided to provide evidence using test data that the product or solution provides a solution to the life problem presented, to indicate the strengths and weaknesses of their products, to mention the market share of their products and the cost calculation according to commercial pectin. Students are asked to complete the relevant sections in Students Worksheet 2.</p> <p>May suggest methods of preparing brochures or advertising posters to promote their products.</p>	<p>They record what has been learned by discussing and answering the questions given in the Product Presentation section in Student Worksheet 2.</p> <p>They can prepare a project to present their products to Trakya Development Agency or TÜBİTAK. The project should also include sustainability; market share of pectin obtained from sunflower heads and cost calculation.</p> <p>They use technological equipment when preparing brochures or advertising posters to advertise their products.</p> <p>They evaluate the products of other groups using the evaluation criteria previously presented by the teacher.</p>



		Offers interaction between groups and, asks students to evaluate the designs of other groups according to the given criteria.	
Sharing What I Learned	30 min	<p>Students are asked to share and discuss what they have learned about the study and record it in Student Worksheet 3.</p> <ul style="list-style-type: none"> - Write what you learned in the theoretical preparation and literature review phase regarding the extraction of pectin from plant sources. - Write what you learned in Prototype Creation Stage on obtaining pectin from plant sources. - Write what you learned during your experimental study on pectin production. - Did you have any problems (if any) during the experimental process? Write what you did to solve them. - Write what you learned in Product Design and research stages on obtaining pectin from plant sources. Have you achieved the goals you aimed for in your work? - Write what you learned in Product Presentation Stage of your product. 	Fill in the relevant spaces in Student Worksheet 3 and reflect their achievements.

Appendixes:

- Student Worksheets (1, 2, 3)
- Flashcards



Worksheets of Green STEAM Teaching Activity: Pectins from Sunflower Head

Student Worksheet 1:

Defining problem

Pectin is a natural polysaccharide found in the cell wall of all plants and fruit peels. Due to its gel-forming feature, it is widely used in the food industry, especially in the production of jam, marmalade and jelly. Also pectin is used in fruit juices, dairy products, sauces, tomato paste, mayonnaise and bakery products in the food industry. Pectic substances are not produced commercially in Turkiye, therefore the pectin is imported from other countries that produce pectin around the world. In our country, fruit pulps which become waste especially in the citrus and other fruit processing sectors, into products with high added value are important in terms of recycling in agricultural production. One of the most grown agricultural products in the Thrace region is sunflower, and the sunflower heads (the seeded part of the sunflower) remain in the field after harvest. Pectin isoation may be a recommended method for bringing these organic agricultural wastes (sunflower heads) into the economy. For this reason, you are asked to obtain pectin, a commercial product that can contribute to the country's economy, by using raw materials that is organic waste and no nutritional value, in this activity.

Duties and Responsibilities

- Describe the problem situation. What is requested from you?

- Complete the table.

Group Members	Duties and Responsibilities

Recalling and Research

- Recalling What is Known and Experienced

Write what you know and experience for the questions given below regarding the problem situation.

What are the professions in the chemical industry?



What does a food engineer do?

Take a jam recipe from your grandmam or mother.

Ask how they adjust the consistency of the jam.

When making jam, ask what they add to the jam other than fruit.

If they added any other ingredients, ask what they used them for.

Recalling and Research

- Areas to Investigate

What do you know about the methods of separation of mixtures?

What are the working areas of food engineering in the chemical industry?

What are pectic substances?

Which substances can be used for pectin isolation?

In what areas is pectin used?

What is a food additive?



Why are the additives added to foods?

Why is pectin added to some foods?

Do you read the ingredients on the packaging of a food when you buying?

What are pH, acidity and alkalinity?

What are the acids and bases encountered in daily life?

Student Worksheet 2:

Design and Create Solution

- The limitations of your study on pectin extraction are as follows.
 - Sunflower head should be used to obtain the product.
 - The product must be obtained in solid form.
 - The product must be odorless.
 - The viscosity of the jam made with the pectin obtained should be close to that of the jam made with commercial pectin.
 - Experimental procedures to be used to obtain the product must be suitable for use in the home environment.
- Write about the different experimental methods you have researched to obtain pectin.
- Which one did you decide to use? Why?
- Write the materials you will use in the experiment and their properties.



- How do you plan to make your product? Write your plan in detail, draw it or create an experiment procedure.

Creating Product and Testing

- Present your plan to your teacher and you can start to experimental after approval from his/her.

- Perform the following tests on the product you will obtain.

1. *Pectin yield (%)*: Weigh the solid pectin you obtained (mP). Calculate the percent pectin yield, taking into account the amount of sunflower sample you used initially.

$$\text{Pectin yield (\%)} = (mP/mA) \times 100$$

mP: Mass of solid pectin obtained (g)

mA: Mass (g) of the pectin source (sunflower head) used at the beginning of the experiment

2. *Absorption capacity (AC) test*: Take three equal sized pieces of your product. Weigh the mass (m_0) of each dry piece. Then, immerse each piece simultaneously in three separate beakers containing 50 mL of distilled water at room temperature, and leave it in distilled water for 6 hours. Before weighing the soaked samples, dry them with a paper towel to remove excess water. Then measure the final mass (m_s) of samples. Calculate the absorption capacity (AC) of your product using the equation given.

$$\text{AC (\%)} = [(m_s - m_0) / m_0] \times 100$$

m_s : Mass of the sample in water (dried with a paper towel)

m_0 : Initial mass of the sample

3. *Viscosity (consistency) test*: Pour 10 mL of distilled water into two long glass test tubes of equal length and diameter. Weigh and add 2 gram of commercial pectin to the first tube, and 2 gram of the obtained pectin to the other, and shake the tubes to dissolve them. For viscosity test, take two identical marbles. Throw one of them into the first tube and press the stopwatch as soon as you



throw it. Stop the stopwatch as soon as the ball touches the base. Repeat the same process for the second tube using the second marbles. Compare the times you obtained.

Product Evaluation and Developing

- Evaluate your product according to the following rubric.

Criterion	Very good (3 point)	Good (2 point)	Bad (1 point)
Pectin yield (%)	> 20 %	20 % - 5 %	< 5 %
Viscosity (consistency)	Same with commercial pectin	Close to commercial pectin	So fluidal Nonfluency
The smell of the product	No	-	Yes
The product fits to target populace	Yes	partially	No
Potential of the product to replace commercial pectin	Yes	partially	No
Should the project support?	Yes	It is need to improve	No
Total point			

- Has your product been a success?

- What changes do you plan on your product?

- What other natural and/or waste products can be used to obtain pectin?



- Brainstorm about what you can do to improve your product and write down in detail the changes you decide to make.

Product Presentation

- To which sector representatives can you present your product? Plan how you will make these relevant people about your product.
- Plan with which advertising method and how you will promote your product.
- Prepare a project to present your product to the Trakya Development Agency. Include sustainability, recycling, market share of pectin obtained from sunflower heads and cost calculation in your project.
- State the strengths and weaknesses of your product?



Student Worksheet 3:

Sharing What I Learned

- Write what you learned during the theoretical preparation and literature survey regarding the extraction of pectin from plant sources.
- Write what you learned during your research on obtaining pectin from plant sources and what you learned about experimental design.
- Write what you learned during your experimental work on pectin production.
- What parts of the experimental process (if any) did you have problems with? Write down what you did to solve them.
- Write what you learned during your research on isolating pectin from plant sources. Have you achieved the goals you aimed for in your work?
- Write what you learned during the presentation phase of your product.
- Are there points of your project that you would like to improve?



Flashcards

Pectic Substances

Pectins are a natural polysaccharide family found in the cell walls of all plants and fruit peels. Its main component is galacturonic acid and has gelling properties.

Viscosity

It is the strength of a fluid against deformation, that is, change in shape, under surface tension. In other words, viscosity is the inverse of fluidity or easy of flow.

Recycling of solid waste in agriculture

Doğal organik atıklardan yeni bir ürün üretilmesi prosesidir. Ör; organik tarım atıklarının hayvan yeminde, kompost üretimi ve biyogaz eldesinde kullanımları; meyve posa ve kabuklarının pektin eldesinde kullanımı.

Agricultural organic waste

The organic plant wastes generated in agricultural production in areas such as fields, gardens, and wastes arising from agriculture-based industry (such as canned food, tomato paste, ready-made food).

Waste management

It is defined as “Prevention of waste generation, reduction at source, reuse, separation according to its characteristics and type, accumulation, collection, temporary storage, transportation, intermediate storage, recycling, recovery including energy recovery, disposal, monitoring, control and inspection activities after disposal.”

Recycling

It is the process of converting wastes that can be reused into a second raw material, by applying physical or chemical processes.

The Gelling

It is an intermediate phase formed between liquid and solid medium. In foods, gelation is defined as the process by which liquid is converted into gel.

What are pectic substances?

Pectic acid
Pectinic acid
Pectin
Protopectin

E code in foods

It is a code number designated for approved additives in packaged food products in European Union countries. For examples; E440 (Pectin), E300 (vit C).

Food Additives (Food Preservatives)

The substances that are not consumed as food on their own, have or do not have nutritional value, and are added to food for various technological purposes such as giving stability, density and color to the food at stages such as production, processing and packaging.

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.

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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	<p>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.</p> <p>For the activity, heterogeneous groups of students should be formed as much as possible.</p> <p>In study groups, the professions given in the worksheet should be shared and the duties and responsibilities of the</p>	<p>Students read and analyze the problem situation presented in the worksheet and discuss it with their peers. In groups, they fully present the problem.</p> <p>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.</p>



		<p>student who undertakes each profession should be determined and written down.</p>	<p>STEM</p>
<p>Remembering and Researching</p>	<p>1 hour</p>	<p>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.</p> <ul style="list-style-type: none"> • 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? <p>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, "<i>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?</i>" It is aimed for them to develop researchable questions such as: They are asked to record their questions in Student Worksheet 1.</p> <p>Afterwards, students are asked to research the answers to these questions and write their answers. They are warned to include the sources they use.</p>	<p>Information and experiences regarding the questions given regarding the problem situation are 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.</p>



<p>Solution Generation-Product Design</p>	<p>1 hour</p>	<p>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.</p> <p>Design Criteria:</p> <ul style="list-style-type: none"> • 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. <p>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.</p> <p>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.</p>	<p>Within the framework of the given design criteria, all ideas considered as problem solutions are put forward and recorded in Student Worksheet 2. By discussing in groups, the most appropriate idea is selected.</p> <p>The materials required for the implementation of the selected idea are also determined.</p> <p>The design of the product is explained in detail and a drawing is made with measurements like an engineer.</p>
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		<p>They are also encouraged to identify the materials needed to implement the chosen idea.</p> <p>All materials required for the event should be prepared in advance.</p> <p>Students should be asked to describe the design of the product in detail and draw it with measurements like an engineer.</p> <p>Students are expected to design a food dryer. It is possible to have many different designs that meet the criteria. The shape, visual appearance and materials used of the dryer may vary depending on the creativity of the students and their research.</p>	
<p>Prototyping and Testing</p>	<p>5 hours</p>	<p>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;</p> <ul style="list-style-type: none"> -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 	<p>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;</p> <ul style="list-style-type: none"> -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



		<p>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.</p> <ul style="list-style-type: none"> - 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. 	<p>graph of the obtained data is created (using a digital tool).</p> <ul style="list-style-type: none"> - 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. <p>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.</p>
<p>Product Introduction, Discussion and Evaluation</p>	<p>1 hour</p>	<p>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.</p> <p>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.</p>	<p>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.</p> <p>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.</p> <p>In addition, the advantages and disadvantages of different design products produced by the groups are discussed with the participation of the whole class.</p>



<p>Developing the Product</p>	<p>30 minutes</p>	<p>Students are asked to discuss among themselves the changes they plan to improve the product and record them in Student Worksheet 2.</p>	<p>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.</p>
<p>Sharing What I Learned</p>	<p>30 minutes</p>	<p>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.</p> <ul style="list-style-type: none"> - 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. 	<p>What is learned is answered and recorded by discussing it in groups within the framework of the questions given in Student Worksheet 3.</p>



Green STEM Teaching Activity Worksheets: Solar Food Dryer

Student Worksheet 1: Need for a Solar Food Dryer

Problem Situation

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 faster and more hygienic industrial drying machines. In addition to tomato paste (which also has an important place in the Turkish economy) and tarhana, which have an important place in the nutrition of the people in Turkey and are made frequently in the summer as winter preparations, we can also provide you with a solar energy-based, environmentally friendly and sustainable cooking product that can be used for hygienic drying of fruits and vegetables. You are asked to design and prototype a food dryer. Do not forget that the drying performance of your dryer in terms of drying speed and hygiene will affect the sales of your dryer.

Our Duties and Responsibilities

Share the following professions in your work group and determine the duties and responsibilities for your friend who undertakes each profession.

- Food engineer:
- Environmental engineer:
- Materials Engineer:
- Industrial Design Engineer:
- Gastronomy Expert:
- Decoration Artist:

Remembering and Researching

-Remembering Known Things and Experiences:

Write down your knowledge and experiences regarding the questions below within the framework of the problem.

-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 amount of absorption of sunlight affect the color of materials? 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 food be stored longer when dried?

Remembering and Researching

-Things to Research:

-To produce solutions, first determine which questions you need to answer and write them below. (*Example: "What are environmentally friendly materials?, What should be taken into consideration when drying foods?, Can foods be dried at any temperature?, "What are the moisture levels in dried fruits/vegetables?"*)

-Then, research the answers to these questions and write down the answers. Also note the sources you used.



Student Worksheet 2: Solar Food Dryer Design

Solution Generation-Product Design

-The features that the “Solar Energy Food Dryer” requested from you must have are as follows. Read these design criteria carefully.

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 of 30*30 cm dimensions.
- It must be aestheticized with local cultural motifs.
- A creative recipe must be created using a dried fruit/vegetable.

- Write or draw all the different ideas you think of for the problem, taking into account the design criteria.

-Which of your ideas did you decide to use? From where?

-Write down the materials you will use.

-How will you make your product? Describe in detail or draw with measurements like an engineer



Prototyping and Testing

-Create a prototype of your product by implementing your plan and using appropriate materials. Test your product using fruits/vegetables. In this process;
-Suggest a method on how to detect the amount of moisture lost in the fruit/vegetable you use to dry.

-Use the research information you have done in the previous section on whether foods can be dried at all temperatures and what the appropriate ambient temperature should be for each fruit/vegetable for drying, and come up with ideas on how this temperature can be achieved while testing the product.

- Determine the amount and percentage of moisture removed from the slicing and drying fruit/vegetable at certain time periods throughout the entire sura. Create a graph of the obtained data (using a digital tool).

- Determine approximately how long it will take for the fruit/vegetable used to dry in the solar food dryer prototype by investigating the moisture content in dried fruits/vegetables.

-At the end of the drying time, measure the amount of microorganisms (bacteria) in the dried fruit/vegetable.

-Also obtain the same type of data by drying in the open under the sun and compare with other data. Comment on the advantages and disadvantages of the two methods.



Product Introduction, Discussion and Evaluation

-Plan how you will introduce your product and inform relevant people and prepare a presentation text. In the presentation text, also include a recipe and visual of your product and the food you will prepare using the principles of gastronomy (the art of cooking) from the foods you dry with your product.

-Evaluate each group's product using the design criteria below. Based on the evaluation made, discuss how well your product solves the problem.

Criteria	Very good (3 points)	Good (2 points)	Bad (1 point)
Food drying with solar energy	Yes	Partially	No
Provides hygienic drying	Yes	Partially	No
Considering the factors that affect the negative change in the color of foods	Yes	Partially	No
Produced with environmentally friendly materials	Yes	Partially	No
It can fit a tray of 30x30 cm dimensions.	Yes	Partially	No
Aestheticizing with local cultural motifs	Yes	Partially	No
Creating a creative recipe using dried fruit/vegetable/tarhana/tomato paste	Yes	Partially	No
Total score:			

Product Development

-What changes do you plan on your product? (Write in detail or redraw your new draft).



Student Worksheet 3: What I Learned from Solar Food Dryer Design

Sharing What I Learned

- What did you learn during the preparation and design phase of the solar food dryer?

What did you learn during the prototyping phase of the solar food dehydrator?

- What did you learn during the testing phase of the solar food dehydrator?

- What did you learn during the product introduction phase of the solar food dryer?

- What did you learn during the product development phase of the solar food dryer?

- What could be the benefits of designing a product that is completely based on solar energy, provides environmentally friendly and sustainable cooking?



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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
<p>Curriculum objectives :</p> <p>Science Learning Outcomes:</p> <ul style="list-style-type: none"> • 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) <p>Engineering Learning Outcomes:</p> <ul style="list-style-type: none"> • 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. <p>Technology Learning Outcomes:</p> <ul style="list-style-type: none"> • 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 . <p>Mathematics Learning Outcomes:</p> <ul style="list-style-type: none"> • 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 :

Worksheets
Digital Tools

Equipment :

white papers
Colorful pencils
Laptop and projector for multimedia screenings



	<p>Construction materials (e.g. plastic bottles, sponges, rubber bands, different perforated fabrics, scissors, tape, glue, wooden sticks, cardboard boxes, cardboard, etc.)</p> <p>thermometers</p> <p>Hygrometer</p> <p>water vapor diffuser</p> <p>water spray bottle</p> <p>Glasses or containers to collect water</p> <p>Different substances on which condensation will occur</p> <p>Mirror</p> <p>Piece of Metal</p>
<p>Literature resources for teachers</p> <p>obligatory :</p> <p>BİLDİREN, Ş., & SARGINCI, M. (2022). An Alternative Solution Proposal to Water Shortage Due to Climate Change: Atmospheric Water Harvesting. <i>Duzce University Ornamental and Medicinal Plants Botanical Garden Journal</i> , 1 (1), 21-35.</p> <p>Sleiti, A.K., Al-Khawaja, H., Al-Khawaja, H., & Al-Ali, M. (2021). Harvesting water from air using adsorption material–Prototype and experimental results. <i>Separation and Purification Technology</i> , 257 , 117921.</p> <p>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. <i>International journal on advanced science, engineering and information technology</i> , 10 (1), 407-412.</p> <p>Verbrugghe, N., & Khan, A.Z. (2023). Water harvesting through fog collectors: a review of conceptual, experimental and operational aspects. <i>International Journal of Low-Carbon Technologies</i> , 18 , 392-403.</p> <p>Jarimi, H., Powell, R., & Riffat, S. (2020). Review of sustainable methods for atmospheric water harvesting. <i>International Journal of Low-Carbon Technologies</i> , 15 (2), 253-276.</p> <p>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. <i>International Communications in Heat and Mass Transfer</i> , 133 , 105961.</p> <p>additional :</p> <p>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:</p>	



<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,Bp9Q9Jrlj0m-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.

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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,Bp9Q9Jrlj0m-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 APPENDIX 1 onto the classroom board to begin the lesson by talking about the value of water and the challenges associated with	-Students give examples of water scarcity in the region they live in and its effects on society. - They discuss ways to obtain clean water - They discuss the concept of water harvesting from the air.



	<p>its scarcity before beginning the activity (In addition, visuals or films showing water scarcity and its effects on communities can be shown if desired.)</p> <ul style="list-style-type: none">-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.	<ul style="list-style-type: none">- 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 .
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		<ul style="list-style-type: none"> -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 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 . 	
<p>Remembering and Research</p>	<p>1 hour</p>	<p>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 .</p> <ul style="list-style-type: none"> - 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? 	<p>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 .</p> <p>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.</p>



		<p>-How does drought affect agricultural products? Which agricultural products are most affected in your region?</p> <p>-What solutions can be suggested to combat drought?</p> <p>-What suggestions can you make about what individuals or societies can do to cope with drought?</p> <p>-What is condensation? How does it happen?</p> <p>-Which factors affect the formation of water vapor in the atmosphere?</p> <p>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?</p> <p>-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.</p> <p>They are cautioned to cite their sources.</p>	
<p>Design and Creation</p>	<p>2 hours</p>	<p>Solution Producing-Product design At the stage , students to design wanted of the product to carry</p>	<p>All suggestions for problem-solving within the parameters of the specified design standards and</p>



	<p>required features , design criteria aspect In Student Worksheet 2 is given .</p> <p>Design Criteria :</p> <p>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.)</p> <p>Water Need: Determine the water need in your region and aim to produce enough water to meet this need.</p> <p>Portability and Easy Installation: The prototype should be aimed to be easy to install and portable, as this will provide flexibility for use in different places at different times.</p> <p>Savings and Efficiency: The aim should be to produce more water by consuming less energy.</p> <p>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?)</p> <p>Reliability and Environmental Impacts: Aim for a design that will keep the vehicle's harmful effects on the environment to a minimum.</p>	<p>technology are made and documented in Student Worksheet 2. Group discussions are used to choose the best idea.</p> <p>The supplies needed to put the chosen idea into practice are identified.</p> <p>A detailed explanation of the product's design is provided, and an engineer-quality sketch is created using precise dimensions.</p> <p>They are cautioned to cite their sources.</p>
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		<p>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.</p> <p>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.</p> <p>They are urged to determine the supplies required to carry out the selected proposal.</p> <p>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.</p>	
<p>Prototype Creating and Testing</p>	<p>5 hours</p>	<p>In the Prototyping and Testing phase, students are guided to create a prototype of the product by implementing their plans and using appropriate</p>	<p>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;</p>



		<p>materials. They are asked to test the resulting product. In this process;</p> <ul style="list-style-type: none"> -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 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. 	<ul style="list-style-type: none"> -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.
<p>Product Introduction, Discussion</p>	<p>1 hour</p>	<p>For Product Promotion, Discussion and Evaluation stage,</p> <ul style="list-style-type: none"> -Each group is asked to explain to the class the features of their model devices and how water is obtained and collected. 	<p>A presentation is prepared by planning how the product will be introduced.</p> <p>The product of each group is evaluated under the guidance of the teacher and with the participation</p>



<p>And Evaluation</p>		<ul style="list-style-type: none"> - 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 concept map or diagram is created by combining the methods worked by each group according to the methods of obtaining water from air. 	<p>of all groups. Based on the evaluation, the class discusses how much the product solves the problem.</p> <p>In addition, the advantages and disadvantages of different design products produced by the groups are discussed with the participation of the whole class.</p>
<p>Product Development</p>	<p>1 hour</p>	<p>Students are asked to discuss among themselves the changes they plan to improve the product and record them in Student Worksheet 2.</p>	<p>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.</p>
<p>What I learned sharing</p>	<p>1 hour</p>	<p>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.</p> <ul style="list-style-type: none"> - 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. 	<p>By having group discussions based on Student Worksheet 3's questions, the lessons are addressed and documented.</p>



Student worksheet 1: Atmospheric Water Harvesting

Problem Status

You thought that you could obtain water from the atmosphere to solve the drought and the resulting water scarcity problem that has begun to make itself felt in our region. You want to design and prototype a water harvesting vehicle to obtain water from the atmosphere. Considering the extent and effects of drought in your region, design a tool to obtain water from the atmosphere.

Things to Research

Research Question:

What questions would you like to answer about atmospheric water harvesting? Write down the questions you want to research:

Research Planning:

Provide a brief outline of the research you can perform and the course of action you should take to address your research topic. (For instance, consider specifics like how bad the drought is where you live, what kind of crop can yield the most, etc.)

Remembering and Research

-Remembering Known Things and Experiences:

Write down your knowledge and experiences regarding the questions below within the framework of the problem.

- 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?

Remembering and Research

-Things to Research:

- How to harvest water from the atmosphere? What methods and technologies can be used?



-What are the environmental and social benefits of harvesting water from the atmosphere?

-Are there any difficulties or limitations in obtaining water from the atmosphere?

Student Worksheet 2: Atmospheric Water Harvesting Project Design

Product Design and Creation Design Criteria:

→ The features that the "Atmospheric Water Harvesting prototype" requested from you must have are as follows. Read these design criteria carefully.

Weather and Climate Conditions: Determine the suitable times and places for water harvesting by examining the climatic conditions of your region. (The rainfall-month graph you draw for your region will give you an idea.)

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 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? Research)

Reliability and Environmental Impacts: Aim for a design that will keep the device's harmful effects on the environment to a minimum.

--Write or draw all the different ideas you can think of for the problem, taking into account the design criteria and the atmospheric water harvesting technology you have chosen.



- Explain which of your ideas you decided to use and why.

-Write down which materials you prefer to use and why.

-Draw a prototype using the dimensions that you have determined. Indicate the purposes of the materials you use on the drawing.



Prototype Creating and Testing

Make a product prototype with materials appropriate for the technology you select. Use a moisture generator, thermometer, and hygrometer to test your product. To display the volume of water you collected over time, make a table or graph. How can one determine a device like that in terms of efficiency? Look into it.

What kind of challenges did you have in this process as you were getting the prototype ready?

-Which elements, such as material selection, dimensions, production process, caused difficulties in the design process?

-At what points in your first design did you feel the need to make changes? What were these changes and their reasons?

-What tests did you subject your prototype to? What tests did it undergo, such as water collection efficiency, durability, and what were the results?



-What kind of problems did you encounter while using the prototype?

-Have you shown the prototype to others? What feedback have you received? What aspects of the prototype does this feedback show you need to improve?

Product Development

-What changes do you plan on your product? (Write in detail or redraw your new prototype)

Student worksheet 3: What Did I learn ?

What I learned sharing

- 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.



Flashcards

Concentration:

Condensation is the process of changing the physical state of a substance from a gas or vapor to a liquid or solid state. It occurs when a gas or vapor cools and loses energy, causing particles to come together and form droplets or solid deposits. Condensation usually occurs when warm, moist air comes into contact with a cooler surface, causing water vapor in the air to condense into liquid water droplets. This process is responsible for the formation of steam, fog, dew, and droplets that appear on the outside of a cold drink or bathroom mirror after a hot shower. Condensation plays a very important role in the water cycle, as it is a mechanism by which water vapor in the atmosphere turns into liquid water, allowing freshwater resources to be replenished .

Sustainability:

Sustainability is the concept of meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. It involves a holistic approach to addressing social, environmental and economic challenges in ways that ensure long-term prosperity, balance and resilience.

Passive Condensation :

involves creating a cold surface that allows water vapor in the air to naturally condense . It can be as simple as placing a cold metal or glass surface in a location with high humidity, such as near a water source or in a foggy area.

Dew Collectors:

Dew collectors are designed to capture water droplets that form at night as a result of condensation . They typically consist of a large surface area, such as a mesh or special material, that helps condense water vapor and collect dew. The collected water is then collected in a collection container.

Atmospheric Water Generators (AWG)

AWGs use a variety of techniques to remove water from the air , such as cooling the air to form condensate or using desiccants to absorb moisture. These devices usually include a cooling system, a condensation chamber, and a filtration system to produce clean drinking water.

Fog Collectors:

In foggy areas or high humidity areas, mist collectors can be used to collect water. They typically consist of large networks of mesh structures placed in the path of the fog. As the mist passes through the mesh, water droplets condense, collect, and store at the bottom.



Hybrid Systems

Some water collection systems combine more than one method to maximize water collection. For example, a system may use a combination of passive condensation, fog collectors, and rainwater harvesting techniques to provide a more reliable and sustainable water supply.

Adsorbent :

Adsorbent is a material that absorbs molecules by adhering to the surface of a gas, liquid or solution. In the adsorption process based on condensation, the adsorbent is generally used to condense gas or vapor molecules. This process occurs when gas molecules accumulate by adhering to the adsorbent surface. It is a tool used to measure humidity in the air.

Hygrometer

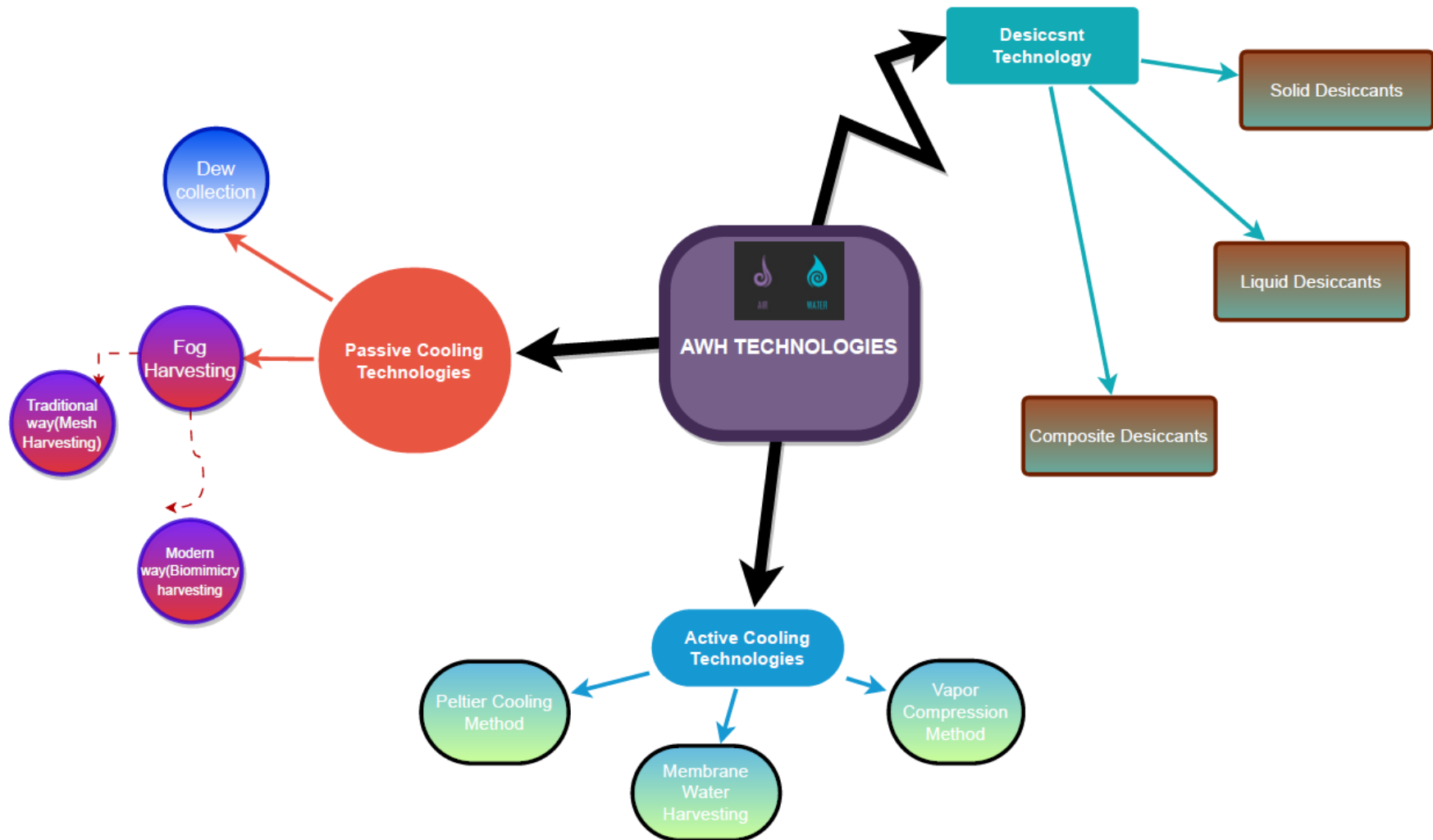
A hygrometer is an instrument used to measure humidity in the air.



WATER HARVESTING TECHNOLOGIES FROM THE ATMOSPHERE

- 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.

Taken from the source.



Teaching materials for Green STEM Training Program for Students of Pedagogical Sciences: Sustainable Technologies in Science Education

Example: Sustainable Technologies in Science Education - Part 1. Teaching Unit via Step-by-Step Instruction

Description of innovative Green STEAM teaching/learning unit

Educational level (students' age): Master Level 2nd Cycle
Subject: Sustainable Technologies in Science Education
Topics: Water Electrolyser, Proton-Exchange Membrane Fuel Cell, Modern Batteries
<p>Curriculum objectives:</p> <ul style="list-style-type: none"> ● 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.
<p>Key words:</p> <p>Water electrolyser, fuel cells, batteries</p>
<p>Learning tools: learning management system (e.g. Moodle), literature databases (e.g. Scopus, Web of Science, Google Scholar, ERIC), presentation, documentation, and spreadsheet software (e.g. PowerPoint, Word, Excel), tools for school experimental data collection, Fuel Cell Car Science Kit - FCJJ-112 or similar etc.</p>
<p>Literature resources for students</p> <p><i>obligatory: /</i></p> <p><i>additional:</i></p> <p>Dinçer, İ., & Erdemir, D. (2023). <i>Introduction to Energy Systems</i>. John Wiley & Sons.</p> <p>Hacker, V., & Mitsushima, S. (Eds.). (2018). <i>Fuel cells and hydrogen: from fundamentals to applied research</i>. Elsevier.</p> <p>He, G. (2024). <i>Electrochemical Energy Storage Technologies Beyond Li-ion Batteries</i>.</p>



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.
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*.
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Teaching method(s): step-by-step laboratory instruction

Scenario of Green STEAM teaching/learning unit

Phase	Required time	Teachers' activity	Students' activity
Pre-laboratory activity	1 hour	<p>Exercise 1: Water Electrolyser</p> <p>The teacher prepares pre-laboratory activity to reinforce prior knowledge of the students as well as present new important concepts for the implementation of experimental work.</p> <p>Suggested questions/topics to be addressed:</p> <ul style="list-style-type: none"> • Definition and basic principles of electrolysis • Historical background and development of electrolysis technology • Explanation of the chemical reactions involved in water electrolysis • Equations representing the electrolysis process and the formation of hydrogen and oxygen gases • Description of electrolysis cells and their components (electrodes, electrolyte, power supply) 	<p>Exercise 1: Water Electrolyser</p> <p>Students participate in the pre-laboratory activity.</p>



		<ul style="list-style-type: none"> • Types of electrolysis cells (e.g., alkaline electrolyzers, PEM electrolyzers) • 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 • Technical and economic challenges associated with water electrolysis • Research advancements and emerging technologies in electrolysis for sustainable energy 	
<p>Laboratory activity</p>	<p>2 hours</p>	<p>Exercise 1: Water Electrolyser In this laboratory activity students construct and operate a simple low-cost electrolyzer using common materials and further explore the potential of hydrogen as a sustainable fuel source for various applications, including fuel cells, transportation, and energy storage. With experimental work students should confirm or refute the following hypothesis: <i>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.</i> The teacher gives instructions for carrying out the following two experiments (for more detailed information, see Appendix 1):</p> <ul style="list-style-type: none"> • EXPERIMENT 1: Building and testing simple water electrolyzer • EXPERIMENT 2: Measuring the pH of the electrolyte before and after electrolysis 	<p>Exercise 1: Water Electrolyser Students carry out the experiments, collect and analyze data and interpret results. To confirm or refute the given hypothesis students execute following investigative tasks:</p> <ol style="list-style-type: none"> 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



		<p>The teacher should circulate among the students' asking questions and making helpful suggestions.</p>	<p>involved in water electrolysis. By introducing different electrode materials, students can significantly alter the electrolyzer's activity, stability, and the selectivity of the electrocatalyst.</p> <p>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.</p> <p>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.</p>
<p>Post-laboratory activity</p>	<p>2 hours</p>	<p>Exercise 1: Water Electrolyser The teacher prepares post-laboratory activity to reinforce concepts, promote critical thinking and communication skills, facilitate the application of knowledge, and assess learning outcomes. Suggested questions/topics to be addressed:</p> <ul style="list-style-type: none"> ● Influence of voltage, current density, temperature, and electrolyte concentration on electrolysis performance ● Optimization strategies for improving electrolysis efficiency and reducing energy consumption ● Production of hydrogen for fuel cells, transportation, and industrial processes ● Energy storage and grid balancing using hydrogen generated from electrolysis 	<p>Exercise 1: Water Electrolyser Students participate in the post-laboratory activity.</p>



		<ul style="list-style-type: none"> • Water treatment, desalination, and environmental remediation applications • Technical and economic challenges associated with water electrolysis • Research advancements and emerging technologies in electrolysis for sustainable energy 	
<p style="text-align: center;">Pre-laboratory activity</p>	<p style="text-align: center;">1 hour</p>	<p>Exercise 2: Proton-exchange membrane fuel cell The teacher prepares pre-laboratory activity to reinforce prior knowledge of the students as well as present new important concepts for the implementation of experimental work. Suggested questions/topics to be addressed:</p> <ul style="list-style-type: none"> • 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. 	<p>Exercise 2: Proton-exchange membrane fuel cell Students participate in the pre-laboratory activity.</p>



- **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.



		<ul style="list-style-type: none"> ● 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. 	
<p>Laboratory activity</p>	<p>2 hours</p>	<p>Exercise 2: Proton-exchange membrane fuel cell In this laboratory activity students assemble a simple hydrogen fuel cell using a commercial chemicals and materials and gain insight into the fundamental principles governing real-scale fuel cell vehicles currently available on the market. With experimental work students should confirm or refute the following hypothesis: <i>By modifying electrode materials, we anticipate observing alterations in output voltage.</i> The teacher gives instructions for carrying out the following two experiments (for more detailed information, see Appendix 2):</p> <ul style="list-style-type: none"> ● EXPERIMENT 1: Building simple hydrogen fuel cell ● EXPERIMENT 2: Assembly of fuel cell car from scientific kit and its operation 	<p>Exercise 2: Proton-exchange membrane fuel cell Students carry out the experiments, collect and analyze data and interpret results. To confirm or refute the given hypothesis students execute following investigative tasks:</p> <ol style="list-style-type: none"> 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



		<p>The teacher should circulate among the students' asking questions and making helpful suggestions.</p>	<p>affect the output voltage, current, and power of the fuel cell system.</p> <ol style="list-style-type: none"> 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
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			alternative energy vehicles (e.g., battery electric vehicles) to understand its strengths, limitations, and competitiveness in the transportation sector.
Post-laboratory activity	2 hours	<p>Exercise 2: Proton-exchange membrane fuel cell The teacher prepares post-laboratory activity to reinforce concepts, promote critical thinking and communication skills, facilitate the application of knowledge, and assess learning outcomes. Suggested questions/topics to be addressed:</p> <ul style="list-style-type: none"> • How does the efficiency of PEM fuel cells compare to other types of fuel cells, such as alkaline or solid oxide fuel cells? • What are the primary factors influencing the durability and longevity of PEM fuel cell stacks under various operating conditions? • How can the cost-effectiveness of PEM fuel cell manufacturing processes be improved to facilitate widespread adoption in transportation and stationary applications? • What advancements in catalyst materials and designs are being explored to enhance the performance and reduce the cost of PEM fuel cells? • 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? • What are the challenges associated with hydrogen storage and distribution for PEM fuel cell-powered vehicles, and what innovative 	<p>Exercise 2: Proton-exchange membrane fuel cell Students participate in the post-laboratory activity.</p>



		<p>solutions are being developed to address these challenges?</p> <ul style="list-style-type: none"> • How can PEM fuel cell technology be integrated with renewable energy sources like solar or wind power to create more sustainable energy systems? • What are the environmental impacts of PEM fuel cell production, operation, and disposal, and how do they compare to traditional combustion-based technologies? • 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? • 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? 	
<p>Pre-laboratory activity</p>	<p>1 hour</p>	<p>Exercise 3: Modern batteries The teacher prepares pre-laboratory activity to reinforce prior knowledge of the students as well as present new important concepts for the implementation of experimental work. Suggested questions/topics to be addressed:</p> <ul style="list-style-type: none"> • Conceptual Understanding: 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 	<p>Exercise 3: Modern batteries Students participate in the pre-laboratory activity.</p>



		<p>cornerstone for further exploration and comprehension.</p> <ul style="list-style-type: none"> ● 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. 	
<p>Laboratory activity</p>	<p>2 hours</p>	<p>Exercise 3: Modern batteries In this laboratory activity students assemble a Zinc-air battery using household materials and chemicals and gain insight into the fundamental principles of Zn-air electrochemistry. With experimental work students should confirm or refute the following hypothesis: <i>Using chemical and mechanical methods one can improve the performance of the Zn-air battery.</i> The teacher gives instructions for carrying out the following experiment (for more detailed information, see Appendix 3):</p> <ul style="list-style-type: none"> ● EXPERIMENT 1: Building simple Zinc-air battery <p>The teacher should circulate among the students' asking questions and making helpful suggestions.</p>	<p>Exercise 3: Modern batteries Students carry out the experiments, collect and analyze data and interpret results. To confirm or refute the given hypothesis students execute following investigative tasks:</p> <ol style="list-style-type: none"> 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



			<p>mechanisms and failure modes through post-mortem analysis, including examination of electrode morphology and chemical composition.</p> <p>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.</p>
<p>Post-laboratory activity</p>	<p>2 hours</p>	<p>Exercise 3: Modern batteries The teacher prepares post-laboratory activity to reinforce concepts, promote critical thinking and communication skills, facilitate the application of knowledge, and assess learning outcomes. Suggested questions/topics to be addressed:</p> <ol style="list-style-type: none"> 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? 	<p>Exercise 3: Modern batteries Students participate in the post-laboratory activity.</p>



	<ol style="list-style-type: none"> 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? 	
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Appendices:

Appendix 1. Exercise 1: Water Electrolyser - *materials for teachers*

Appendix 2. Exercise 2: Proton-exchange membrane fuel cell - *materials for teachers*

Appendix 3. Exercise 3: Modern batteries - *materials for teachers*



Appendix 1.

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.



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: Building 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.
1. 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.
2. 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.
3. 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.
4. 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



Co-funded by
the European Union

Required materials:

- universal pH indicator
- vinegar
- baking soda

Procedure:

1. If the pH is alkaline ($\text{pH} > 7$), 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 ($\text{pH} < 7$), 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-11² or similar

Procedure:

1. Follow the procedure from the manufacturer's instructions³⁻⁹

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Appendix 3.

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 BASIS¹

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:

Conceptual Understanding: 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 as 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% H₂O₂
 - e. Addition of 5 mL of 3% H₂O₂ 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.

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- How to Make a Battery with Metal, Air, and Saltwater
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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
<p>Curriculum objectives:</p> <ul style="list-style-type: none"> ● 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 electrolyzers. ● 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



<p><i>obligatory: /</i> <i>additional:</i></p> <p>Dinçer, İ., & Erdemir, D. (2023). <i>Introduction to Energy Systems</i>. John Wiley & Sons. Ferk Savec, Vesna (2010). <i>Projektno učno delo pri učenju naravoslovnih vsebin : učbenik</i>. Maribor: Fakulteta za naravoslovje in matematiko. Hacker, V., & Mitsushima, S. (Eds.). (2018). <i>Fuel cells and hydrogen: from fundamentals to applied research</i>. Elsevier. He, G. (2024). <i>Electrochemical Energy Storage Technologies Beyond Li-ion Batteries</i>. Korthauer, R. (Ed.). (2018). <i>Lithium-ion batteries: basics and applications</i>. Springer. Monconduit, L., & Croguennec, L. (2021). <i>Les batteries Na-ion</i>. ISTE Group.</p>
<p>Literature resources for (future) teachers</p> <p><i>Obligatory/additional:</i></p> <p>Dinçer, İ., & Erdemir, D. (2023). <i>Introduction to Energy Systems</i>. John Wiley & Sons. Ferk Savec, Vesna (2010). <i>Projektno učno delo pri učenju naravoslovnih vsebin : učbenik</i>. Maribor: Fakulteta za naravoslovje in matematiko. Hacker, V., & Mitsushima, S. (Eds.). (2018). <i>Fuel cells and hydrogen: from fundamentals to applied research</i>. Elsevier. He, G. (2024). <i>Electrochemical Energy Storage Technologies Beyond Li-ion Batteries</i>. Korthauer, R. (Ed.). (2018). <i>Lithium-ion batteries: basics and applications</i>. Springer. Monconduit, L., & Croguennec, L. (2021). <i>Les batteries Na-ion</i>. ISTE Group.</p>
<p>Teaching method(s): project-based learning, experimental work</p>

Scenario of Green STEAM teaching/learning unit

Phase	Required time	Teachers' activity	Students' activity
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<p>Initiative</p>	<p>1 hour</p>	<p>The teacher briefly introduces the students to what project-based learning (PBL) is and what are its main phases.</p> <p>The teacher also presents a collaborative environment (e.g. Microsoft Teams), the templates that will guide them through all the phases and will be included in the portfolio or result of each group's PBL.</p> <p>The teacher then leads the initiative, the first phase of the students' PBL work.</p> <p>In the initiative phase, it is important to provide the best possible opportunities for a spontaneous and open string of proposals and initiatives. All members of the group (students), the teacher/group of teachers or someone outside the group can submit initiative proposals. In any case, it is desirable that the initiative comes from the students, as they are then more committed and interested in continuing the project work.</p> <p>The activity of students in this phase can be encouraged and channelled into various activities: e.g. brainstorming, finding broader concepts for a particular topic, and asking broader questions, formulating proposals in small groups and sometimes ideas arise spontaneously, e.g. as a result of a particular event (e.g. as response to a current topic that is discussed in the daily media).</p> <p>We guide the students to primarily discuss about/choose from the following suggested topics:</p> <ul style="list-style-type: none"> ● <i>Hydrogen Fuel Cells</i> ● <i>Electrolysers</i> 	<p>Students actively participate and in groups develop their own projects.</p> <p>The students exchange ideas, take part in the discussion, and think about a topic for their group's project that interests them.</p> <p>Students submit the completed project initiative template.</p>
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		<ul style="list-style-type: none"> ● <i>Lithium-ion (Li-ion) Batteries</i> ● <i>Sodium-ion (Na-ion) Batteries</i> ● <i>Photovoltaics</i> ● <i>Wind Turbines</i> <p>In addition to the suggested topics, students can also suggest other topics that interest them and are related to the course content – green/sustainable technologies that represent a diverse array of innovations aimed at mitigating environmental impact and promoting ecological sustainability.</p>	
<p>Sketching</p>	<p>1 hour</p>	<p>In the stage of sketching the project, the students discuss and exchange views on the selected topics. The teacher should direct the discussion in such a way that it leads to conclusions in the following areas:</p> <p>(1) Defining the starting point of the PBL - what the students are interested in within the selected topic area and what they would like to investigate further, the aims of their PBL work, alternative ideas for the research.</p> <p>(2) Feasibility of the project - considering the availability of the necessary tools, materials, chemicals, the possibility of interdisciplinary collaboration and co-operation with external experts (e.g. from industry).</p> <p>In addition to acquiring knowledge and developing skills, participants also develop interpersonal skills during project-based learning, e.g. the ability to work in a group; the ability to express opinions and positions clearly but respectfully and constructively; the ability to resolve disagreements and misunderstandings,</p>	<p>Students actively participate and in groups develop their own projects.</p> <p>Students define the starting point of their PBL and think about feasibility of their project (e.g. what tasks they will need to carry out during the PBL, how will they get the needed materials, tools, consider concerns that might affect the implementation of the PBL and how they will try to overcome them - if you encounter insurmountable obstacles they should redesign the project concept accordingly).</p> <p>Students submit the completed project sketch template.</p>



		etc. For good communication during PBL work, it is therefore suggested that students agree at this stage on the rules to be followed during the project.	
Planning	1 hour	<p>Project implementation planning is the phase in which the members of the project team formulate their work plan for implementation. The teacher guides students in defining the relevant research questions and/or hypotheses. The research questions should be solved through theoretical research and experimental work. The teacher encourages each member of the group to say what they want to do and what they want to be involved in. At this phase, it is also necessary for the teacher to guide the students to define in detail the tasks that are crucial for the successful realisation of the project. Based on the defined tasks, the work should be sensibly divided among the members of the project group according to the priorities of the individuals and regarding the logical flow of the project.</p>	<p>Students actively participate and in groups develop their own projects. In line with the objectives of the PBL, students define the relevant research questions and/or hypotheses. They define and break-down the tasks to be carried out as well as think about the timing of the workflow and division of the tasks among PBL team members. Students submit the completed project planning template.</p>
Implementation	20 hours	<p>Part 1: Literature study - work in the computer classroom (5 hours) The teacher introduces students to literature databases (e.g. Scopus, Web of Science, Google Scholar, ERIC) and different ways of searching for relevant literature in them.</p> <p>Part 2: Development and optimization of experimental work in the laboratory (15 hours) The teacher circulates between groups giving meaningful feedback, instructions, offering help and ensuring that students consider and follow chemical safety.</p>	<p>Students actively participate and in groups develop their own projects.</p> <p>Part 1: Literature study - work in the computer classroom (5 hours) Students use various literature databases to conduct a literature study on the key concepts of the chosen topic and explore the possibilities for experimental work through a literature review. Students submit completed literature study template.</p> <p>Part 2: Development and optimization of experimental work in the laboratory (15 hours)</p>



			<p>After examining the theoretical starting points, students develop and optimise selected experimental work in the laboratory on their specific topic.</p> <p>In this phase, students should formulate a hypothesis, determine the experimental design and setup, and write a method for data collection. Using their plan, students then carry out the experiment and collect data, which they analyse, interpret, and draw conclusions from. They compare the experimental results with the findings from the literature.</p> <p>Students submit the completed template for the development and optimisation of the experimental work.</p>
<p>Concluding phase</p>	<p>7 hours</p>	<p>Part 1: <i>Students present their project</i> (4 hours) The teacher provides meaningful feedback.</p> <p>Part 2: <i>Joint synthesis and reflection</i> (3 hours) When all students are familiar with the green/sustainable technologies studied by individual project groups, the teacher leads a joint synthesis and discussion that should foster a practical understanding of the technologies' real-world applications and stimulate critical thinking about their role in a sustainable energy future.</p>	<p>Students actively participate and in groups develop their own projects.</p> <p>Part 1: <i>Students present their project</i> (4 hours) Students prepare a short digital poster presentation (e.g. with Canva, PowerPoint) of their project and present it to other students and others involved in the project.</p> <p>Part 2: <i>Joint discussion and reflection</i> (3 hours) Students participate in joint synthesis and discussion. They participate in co-creating a joint report and presentation about green/sustainable technologies and their role in a sustainable energy future.</p>



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