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Course Syllabus

SUSTAINABLE TECHNOLOGIES IN SCIENCE EDUCATION



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Course 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.



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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.
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- 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.



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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

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