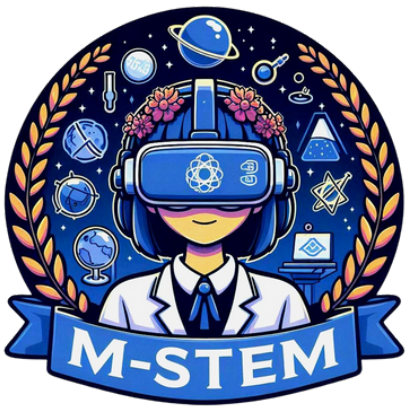

M-STEM

LESSON PLAN

NUCLEAR FISSION AND NUCLEAR FUSION

METAVERSE-BASED STEM EDUCATION FOR A SUSTAINABLE AND RESILIENT FUTURE

2023-1-FR01-KA220-SCH-000151516

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Purpose of the lesson

Nuclear energy is a miracle that can do wonders for the existence of life on earth or turn everything into a nightmare - it depends on how and for what purpose it is used. Teaching students about **nuclear fusion and nuclear fission** is crucial because these concepts are fundamental for understanding **modern energy production** and the **role of nuclear technology in society**. By learning about these processes, students can appreciate the **scientific principles that drive energy generation** and the potential for sustainable energy through fusion. Moreover, this lesson offers students the possibility to discuss the **benefits and risks associated with nuclear power**, thus fostering critical thinking and informed decision-making.

Description of the lesson

This lesson is aimed at helping students, aged 16-19, **understand nuclear fission, nuclear fusion and nuclear energy**; it is also targeted at familiarizing them with the **components of a nuclear reactor** and at offering them the chance to gain a well-rounded understanding of contemporary energy issues. By exploring the principles of nuclear fission, students will grasp how energy is produced on a massive scale, providing a clean alternative to fossil fuels. The activities included in this lesson plan will also teach students about the **optimal conditions** for the **safe functioning of a nuclear reactor**. Additionally, the scientific contents and didactical methods used will prepare students for **potential careers** in science, technology, engineering, and mathematics (**STEM**) fields, where they can contribute to innovative solutions for energy challenges.

Lesson teaching method

In the teaching process, **active-participatory, student-centered learning techniques and methods** will be used. Participants in the activities will be trained to use the information acquired in practical exercises, **to collaborate** in completing work tasks, which will contribute to increasing intrinsic motivation for learning. Students will be **challenged to discover facts** and to bring arguments for and against. **Metaverse** technology will be used to create **immersive learning experiences**, in which students will experiment with the creation of a nuclear reactor, produce nuclear fission reactions. Thus, with the help of **interactive exercises and practical applications**, students will gain an advanced understanding of new content and be able to identify different causes of abnormal operation of a nuclear reactor.

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Learning objectives

The lesson aims to convey knowledge/acquire practical skills to students, with the help of which they will be able to:

- **understand** nuclear fission and chain reaction;
- **identify** the structural elements of a nuclear reactor;
- **(virtually) assemble** a nuclear reactor
- **analyze/identify** possible effects of nuclear accidents
- **critically assess** the impact of the use of nuclear technologies on society and nature.

Lesson plan

1. Introduction (5 minutes)

In order to prepare students for the new content, the teacher asks them to **present the poste**r titled "Applying measures to protect the environment and oneself from nuclear radiation", which was the theme of the previous lesson. Divided into 4 groups, students present the poster they created for the lesson. A gallery tour is organized, a ***peer-to-peer* evaluation is carried out**, and students will express their appreciation in writing, using post-its.

2. Lesson progress (50 minutes)

a) Presentation of the concepts and objectives of the lesson (10 minutes)
The teacher projects two images – one illustrating the effects that the destructive use of nuclear energy has on life, and one capturing some of the benefits of nuclear energy for people and the environment. Organized into two groups, the students are invited to reflect on the content of the two images and add new ideas.
The teacher introduces the lesson objectives to the students and ensures that they understand the concepts they will be working with during the activities (nuclear fission reaction, chain reaction, critical mass, nuclear reactor, etc.). To do this, the teacher uses definitions of terms and suggestive images.

b) Interactive activities (40 minutes)
i). Nuclear fission (10 minutes)
With the help of a volunteer student, the teacher will demonstrate to the students the process of nuclear fission. Guided by the teacher, the student will press a button to release a neutron that will hit a nucleus of $^{235}_{92}U$. After capturing a slow neutron, the uranium-235 nucleus splits into two intermediate nuclei of different masses and 2-3 neutrons.

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Students will notice that:

- the interaction potential energy for the uranium-235 nucleus is *minimum*
- after capturing the slow neutron, the total energy of the nucleus *increases*
- following the fission of the uranium-235 nucleus by capturing a slow neutron, energy equivalent to the difference in mass is released; *the result is two lighter nuclei* that have kinetic energy equal to the reaction energy Q=200MeV and several high-speed neutrons (fast neutrons).

The teacher explains to the students that the fission reaction of heavy nuclei (A>60) that have an average binding energy lower than the maximum of 8.6MeV is *exothermic*. The controlled fission reaction can be achieved using uranium 235 which fissions upon interaction with thermal neutrons (slow-speed neutrons, with kinetic energy much lower than 1MeV).

ii). Chain reaction (10 minutes)

Students will be divided into two groups. Each team will appoint a representative who will use Metaverse technology for the following tasks:

- group 1 – fission chain reaction simulation: the designated student will press a button to release several neutrons that will hit several targets (unleashed uranium 235 nuclei). Using a counter, students will observe the number of nuclei that have fissioned. Students can rotate the neutron source to change the direction in which the neutron is sent, which will help them observe whether the chain fission reaction is influenced by the direction from which the neutron is released.
- group 2 - simulation of a nuclear explosion: the designated student will enlarge the space in which the chain fission reaction will occur, place a large number of uranium-235 nuclei in the enclosure, then initiate the reaction by releasing a neutron, pressing a button related to the activity. Students will notice that when the nuclei are placed in the enclosure, for larger radii of the enclosure that allow a large number of uranium-235 nuclei to fission (between 60 and 100), a nuclear explosion can occur.

iii). Building a nuclear reactor (20 minutes)

Students will be divided into teams to complete the following task: building a nuclear reactor. For this, they will have a list of possible components for creating a nuclear reactor, but the list will also include some that are not part of the nuclear reactor. To begin with, students will select component elements to complete the task. Later, they will assemble them appropriately in order to build the nuclear reactor. Students will have an image of the final product they have to create.

To carry out the practical activity, students will also receive information about the optimal conditions for normal operation of the nuclear reactor (stable temperature, proper functioning of the moderator, adequate neutron flux, efficient positioning of the control rods, constant coolant flow, etc.).

Subsequently, students will be challenged to identify possible malfunctions of a nuclear reactor (e.g., a break or leak in the cooling system, failure of control rod mechanisms or malfunction of neutron detectors , overheating of the reactor core , structural failure in the containment building , damage to fuel rods, etc.) and identify solutions.

3. **Feedback on information/skills acquired (5 minutes)**

The teacher will receive feedback, namely assess whether and to what extent the students have acquired new knowledge and skills by applying a test, such as the following:

Multiple Choice Questions (One correct answer)

1. Which of the following is a key component of a nuclear reactor?
    - A) Solar panels
    - B) Control rods
    - C) Wind turbines
    - D) Combustion chamber
2. What is the goal of using moderators in a nuclear reactor?
    - A) To slow down neutrons
    - B) To increase temperature
    - C) To absorb radioactive waste
    - D) To produce steam
3. Which of the following is a potential consequence of a nuclear accident?
    - A) Increased energy efficiency
    - B) Release of radioactive materials
    - C) Enhanced plant growth
    - D) Improved air quality
4. In nuclear fission, what happens to the nucleus of an atom?
    - A) It combines with another nucleus
    - B) It evaporates into gas
    - C) It remains unchanged
    - D) It splits into smaller nuclei

- 5. What is the optimal condition for a nuclear reactor to function safely?
  - A) Controlled temperature and adequate coolant flow
  - B) High pressure and low temperature
  - C) Complete absence of control rods
  - D) Excessive neutron flux
- 6. How does changing the direction of the neutron source potentially affect the fission chain reaction?
  - A) It has no effect on the reaction
  - B) It allows for a better measurement of temperature
  - C) It influences the likelihood of neutrons hitting uranium-235 nuclei
  - D) It increases the number of neutrons available for fission

True/False Questions

1. **True or False**: Nuclear fusion produces more energy than nuclear fission.
2. **True or False:** Nuclear fission can lead to the production of long-lived radioactive waste.
3. **True or False:** Control rods in a nuclear reactor are used to absorb neutrons and regulate the fission process.
4. **True or False:** Nuclear energy can only be used for peaceful purposes and has no potential for destruction.

Answer key

Multiple Choice Questions: 1.B, 2.A, 3.B, 4.D, 5A, 6C,
True/False Questions 1.True, 2. True, 3. True 4. False

4. Homework (5 minutes)

Activity 1

Students will be asked to watch two video clips by accessing the following addresses:

- https://www.youtube.com/watch?v=0l7QFfsHBks
- https://www.youtube.com/watch?v=Aza-2wopCFY .

Based on the examples included in the films proposed for viewing, students will create a presentation on the effects of nuclear accidents. To create the presentation, students will use a digital application of their choice.

Activity 2

Students will be divided into groups and will create a concept map regarding the impact of technologies on society and nature.

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Lesson table

Nuclear fission and nuclear fusion	
Introduction Preparing students for the new content (presentation of posters designed as homework of the previous class) Presentation of the concepts and objectives of the lesson • nuclear fission reaction, • chain reaction, • critical mass, • nuclear reactor, etc.)	15
i). Nuclear fission. Nuclear reactor A volunteer student, guided by the teacher, will demonstrate the process of nuclear fission	10
ii). Chain reaction Organized into two groups, students will • simulate a fission chain reaction • simulate a nuclear chain reaction • students will discuss what they have noticed while performing the tasks	10
iii). Building a nuclear reactor Divided into teams, students will complete the following task: building a nuclear reactor • Students will have some date to guide them in carrying out the task • Students will identify possible malfunctions of a nuclear reactor • Students will find possible solutions to the problems	20

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Lesson table

The importance of PH in every day life	
Assessment of acquired knowledge Teacher assesses students' knowledge, using a quiz	5
Homework • **Activity 1** Students will create a presentation on the effects of nuclear accidents (students can use whatever informative information they can find, but the teacher will also provide some videos) • **Activity 2** Students will be divided into groups and will create a concept map regarding the impact of technologies on society and nature.	5

Lesson resources

Resources needed for the lesson

Lesson resources

To carry out the activities, various informative materials on the topic of the lesson were used, from which the scientific content was selected, which was subsequently presented synthetically in a Power Point presentation.

Digital resources

- https://phet.colorado.edu/ro/simulation/nuclear-fission
- https://www.yo u tube.com/watch?v=0l7QFfsHBks
- https://www.yout u be.com/watch?v=Aza-2wopCFY
- https://www.youtube.com/watch?v=dGr8VaITKbA
- https://www.youtube.com/watch?v=3nvkHjn1ETU
- https://www.youtube.com/watch?v=Kg_aSG2ZI6A
- https://www.youtube.com/watch?v=a__E88op6cc
- https://iceds.anu.edu.au/news-events/news/what%E2%80%99s-difference-between-fusion-and-fission-nuclear-physicist-explains
- https://www.solarreviews.com/blog/nuclear-energy-pros-and-cons

Evaluation and indicators

Assessment will be carried out throughout the learning activities; the teacher will assess the degree of involvement of the students in completing the tasks, applying knowledge in the construction of the nuclear reactor, identifying the dangers that may arise as a result of the improper use of nuclear energy, with disastrous effects on people and the environment. The teacher will provide feedback in a structured manner and will identify areas that require improvement. The teacher will assess the clarity and depth of the ideas expressed, their originality, as well as their level of applicability in everyday life.

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Evaluation and indicators

Criteria	Excellent	Good	Satisfactory	Needs improvement
Understanding of Nuclear Fission and Fusion	Thorough understanding; clearly explains concepts and differences.	Good understanding; explains key concepts with minor errors.	Basic understanding; identifies concepts but lacks detail.	Limited understanding; struggles to explain concepts.
Nuclear Chain Reaction Knowledge	Provides a detailed explanation of the chain reaction process and its significance.	Explains the chain reaction with some details.	Basic description of the chain reaction process.	Limited explanation; major gaps in understanding.
Benefits of Nuclear Energy	Clearly articulates multiple benefits, supported by examples and relevance.	Identifies several benefits with some examples.	Lists benefits but lacks depth or examples.	Limited list of benefits; vague understanding.
Components of a Nuclear Reactor	Accurately identifies and describes all key components and their functions.	Identifies key components but with minor inaccuracies.	Names several components but lacks detailed descriptions.	Limited identification of components; significant gaps.
Optimum Conditions for Functioning	Thoroughly explains optimal conditions and their importance for safety.	Explains conditions with some details and relevance.	Basic understanding of conditions; lacks comprehensive explanations.	Limited explanation; unclear about safety significance.
Overall Presentation and Clarity	Ideas are exceptionally clear and well-organized; excellent use of terminology.	Clear presentation with minor issues in organization or terminology	Some clarity; organization could be improved.	Limited clarity; ideas are poorly organized.

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Overview of the lesson

As global energy demands increase, knowledge regarding nuclear fusion, fission and nuclear reactors is essential, as it equips students with the scientific foundation needed to engage in discussions about sustainable energy solutions. This lesson focuses not only on providing theoretical understanding of these concepts and processes, but also on developing several practical skills. Moreover, this lesson challenges students to understand the necessary conditions for the correct functioning of a nuclear reactor, thus emphasizing the importance of safety, regulation, and ethical responsibility in technology use. Students are also encouraged to reflect on the benefits and drawbacks of nuclear energy. Through the activities included in the lesson, as well as through the methodological approach, students engage thoughtfully with energy issues and can contribute to the development of innovative solutions for a sustainable future. Equally important, the lesson offers students the possibility to improve problem-solving skills, team work and collaboration, analytical thinking, The simulation exercises, designed with the help of the Metaverse technology, will provide practical experience in applying theoretical concepts, reinforcing learning through active participation in the design process. Students will thus be prepared for future studies or careers in science, technology, engineering, and mathematics (STEM).

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THERE ARE MANY VARIATIONS OF PASSAGES

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