Erasmus+	Project funded by: **Erasmus+ / Key Action 2 - Cooperation for innovation and the exchange of good practices, Strategic Partnerships for school education** **(European Commission, EACEA)**

WORLD OF PHYSICS

Deliverable Number	IO2
Deliverable Title	**A2 Technical Guide for Trainers (Trainer's Handbook)**
Intellectual Output Title	**Virtual 3D World for Teaching Physics**
Activity description	Elaboration of the Technical Guide for Trainers, containing the necessary information for school teachers to take advantage of the 3D Training Platform and successfully integrate it in their classes as an educational support tool.
Authors	**CNR ITD, UCY, UPAT, CTE, New EDU, CTI**
Status (D: draft; RD: revised draft; F: final)	**F**
Date (versioning)	v.1.3.20.11.2018.cte

Document History

Authors	Reviewer	Date	File suffix [Version.Revision]	Approval
CNR ITD	UPAT	19.04.2018	1.0	UPAT Yes
UCY	CTI	20.09.2018	1.1	CTI Yes
New EDU	CTI	25.10.2018	1.2	CTI Yes
CTI	CTE	20.11.2018	1.3	CTE Yes

List of abbreviations

Abbreviation	Definition
MMOW	Massively Multiplayer Online World
WOP	World of Physics
NPC	Non-Player Character
IBSE	Inquiry Based Science Education

Table of contents

Virtual Worlds

The virtual worlds (Massively Multiplayer Online Worlds - MMOW) are computer-generated environments with two or three-dimensional graphics in which users, through the use of a virtual avatar (their persona representation in the 3D World), live and experience, alone or interacting with the other visitors, the possibilities offered by the environment.

Within these environments it is possible to experiment situations, enter contexts otherwise impossible to experience, manipulate objects, get in touch with new people. These environments can refer to fantasy or real worlds. Within the environments there are rules of behaviour to follow. Communication between users can be textual, vocal, gestural and in some cases even tactile.

Virtual worlds were born initially for gaming purposes, but in recent years there has been a tendency to design training environments, especially in the health sector, and for teaching.

Virtual worlds for Education

Virtual worlds in education are an important powerful and effective tool to support the teaching and learning processes, according to the constructivist approach. In particular, virtual worlds allow to experiment specific situations within settings constructed as scenarios in which to act behaviours to learn. Learning is the result of an experience that is stirred up on the surrounding reality, manipulating it and observing the way in which it reacts and changes.

Virtual worlds are a useful "realistic" way to carry out effective educational experiments and simulations.

The use of virtual worlds aimed at experimenting with Physics may seem contradictory for a discipline that confronts real natural phenomena. Virtual worlds are a varied learning environment; the teachers can prepare interactive lessons, with multimedia contents in an immersive environment, the students can simulate and experiment even complex physical phenomena, which have the advantage of being easily reproducible. From an educational point of view, virtual worlds are a facilitator from motivational, iconic as well as procedural points of view. Students are more motivated, they like for play, to experiment, analyse data, make physical models, they are also more likely to "study" through an instrument that they consider "familiar" and "fashionable". Using a language that is close to the world of young people allows to create learning environments based on the active involvement of students. Researchers have found some crucial characteristics for the successful integration in the traditional curriculum of virtual worlds. Effective implemented virtual worlds allow the learners to visualize or enact learning scenarios through their active engagement. The key to efficacy of virtual worlds is INTERACTIVITY, rather than immersion. This means simply that students are “learning by doing” in these environments. Virtual worlds can be applied to create spaces that transcend safety or distance parameters. Easiness of navigation through the virtual worlds seems to make the user experience better and also improve the learning motivation. Thus, teachers best serve as facilitators in the discovery process, rather than problem solvers.

The WOP Project

The aim of the WOP Project ("World of Physics: an innovative educational environment for virtual reality for school physics education", Agreement No. 2016-1-CY01-KA201-017371) is to support students in the study of physics. The learning environment adopts a pedagogical approach that, through 3D virtual reality, offers engaging, fun and effective educational opportunities. World of Physics (WoP) offers a 3D virtual environment designed to help students learn physics using the IBSE strategy in virtual laboratories.

According to the constructivist theory of Jean Piaget [1] people build their knowledge through the experiences and internal re-elaboration that each individual works in relation to their sensations, knowledge, beliefs and emotions.

From this perspective, the learning process is also the result of a continuous interaction between the information to be learned and the interpretation built on the basis of previous knowledge, the context and the personal meaning attributed to them. Many educational strategies are based on the principle of constructivism; one of the most effective for science education is the strategy called Inquiry Based Science Education (IBSE). It refers to a teaching methodology aimed to an active learning that leads to a profound knowledge and not only to memory. This methodology considers the scientific investigative nature and the manner in which students learn and start from the idea that the heart of scientific learning is the direct experience. The students show a natural curiosity that is an expression of an attempt to understand the world around them and they build their knowledge by reflecting experience. The IBSE methodology gives great importance not only for experimentation but also for collaboration, the ability to reflect, discuss, document, present and share the results of the investigations.

Adopting this training method allows students to develop an understanding of the scientific aspects of the world through the development and use of investigative skills [2]. In particular, the IBSE bases [3] its principles on some general rules, primarily on the belief that the student is able to control his own learning process by working as scientists, by performing experiments, collecting and analysing data.

The characteristics of this learning process are therefore linked to the exploration of the environment, to creating hypotheses to be refuted through experimentation. Starting from these considerations, the project "World of Physics: an environment of innovative virtual reality for the education of physics" funded by the European Union under the Erasmus+ program has been implemented. The aim of the project is to accompany students in the study and learning of physics through new educational technologies. World of Physics (WoP) offers a 3D interactive virtual environment designed to help students learn physics using the IBSE strategy and virtual laboratories.

Students have the opportunity to: visit the virtual laboratories of WoP, carry out experiments, explore procedures and phenomena and deepen their knowledge through educational content and resources. In virtual laboratories they can also investigate unobservable phenomena, conducting impossible experiments in the real context [8]. In addition, students have "non-player characters" available to help them analyse and understand the physical phenomena simulated in the virtual world.

The results described in the report "Physical Education in Schools of Secondary Education in Europe" [4], produced within the World of Physics project, show that students in Europe have a marked decline in interest in scientific studies and they have very low knowledge in both physics and mathematics, they do not like to read science books in their free time and consider it boring. The results of this report highlight the importance and educational value of creating 3D virtual learning environments, as they can motivate students through innovative and engaging study experiences. Furthermore, virtual worlds encourage student empowerment through more interactivity and more constructive ways of learning [5] [6].

Development of Learning Scenarios in WOP

The development of the training path of each of the WOP virtual world scenarios required the collaboration of numerous experts with professional roles, such as: physics experts, pedagogical experts, software developers and teachers.

To foster an effective collaboration among the various experts, a set of templates were used to standardize each stage of development. Each expert, involved in the design phase, was initially trained on the use and exploitation of the virtual worlds and their resources. OpenSimulator allows an easily integration of a set of educational resources, such as:

- Slideshows;
- Notecards;
- Quizzes;
- Non-Player Characters (NPC);
- Multimedia presentations;
- 2D Simulations;
- 3D Simulations.

The template used to describe scenarios is composed by the following sections:

- **Introduction:** identification of the learning objectives and prerequisites of the student in order to complete the scenarios;
- **Locations**: descriptions of the virtual world environment, the laboratories and the objects required for the experiments.
- **List of activities**: a list containing all the activities in the scenario. Activities can be simple educational resources (such as notecards, slide-shows, and quizzes) or multimedia presentations and virtual laboratories in 2D or 3D modes. For each educational resource produced (notecard, slide-show, quiz or multimedia presentation), a specific template has been developed to be completed by teachers and pedagogues.

Description of the experimental activities and pedagogical model: this section describes in a formal way the activity that the user must perform within the developed scenarios and the pedagogical model on which each activity is based. In particular, this section contains: description of the virtual laboratories and the objects from them (some images of the objects are included in the template), description about the interaction between objects and users, an explanation on physical laws experienced in the lab.

All documents developed by the teachers and the pedagogues are submitted for validation to the physics experts that can propose some changes. Finally, the validated documents are transferred to the developers for the creation of the virtual environment with the most appropriate game mechanics [9].

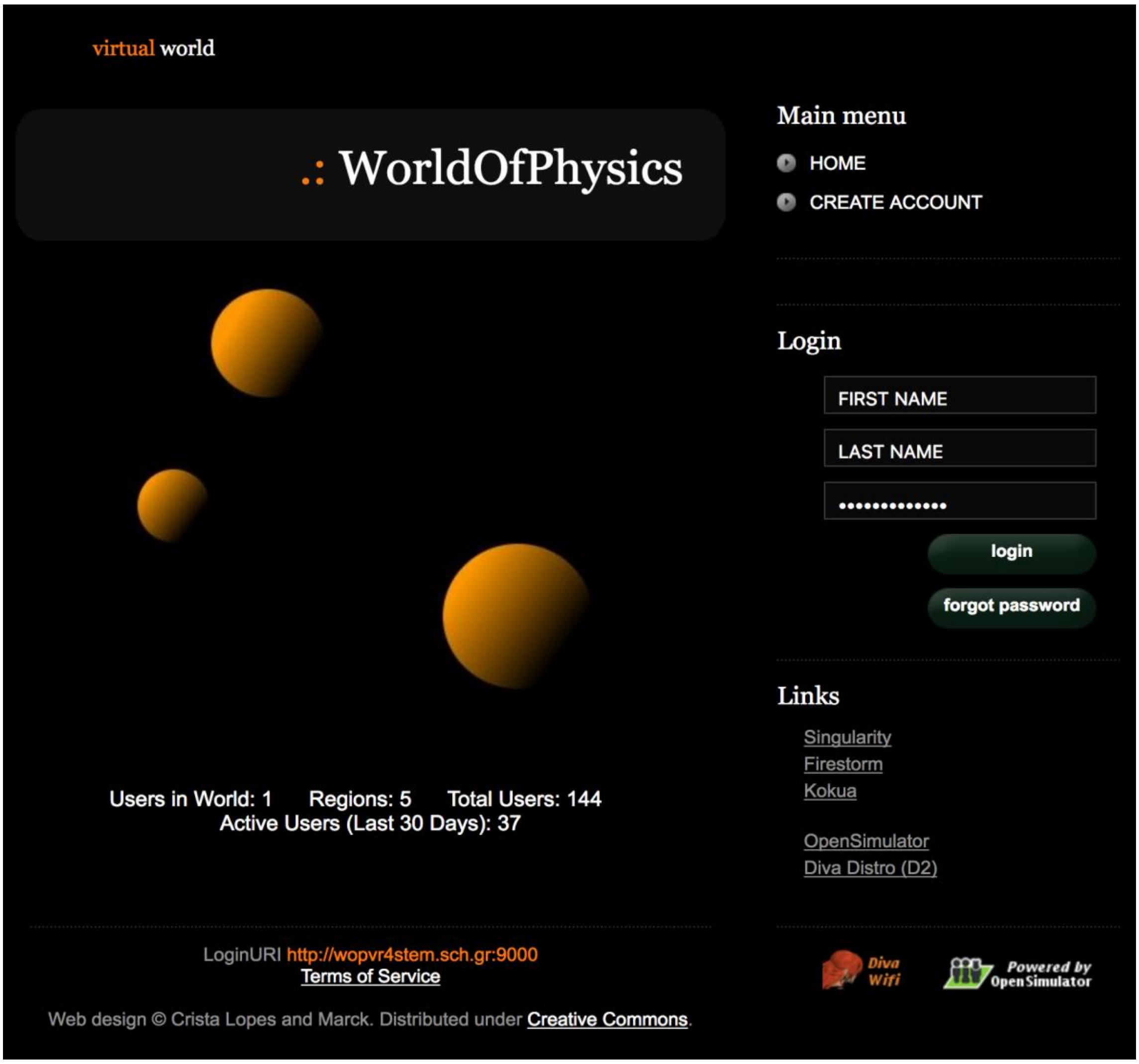
Once the software development phase has been completed, the 3D environment is again validated by the physics expert to verify that the physical phenomena simulated are equivalent to the real ones; finally, a further validation by the teachers and pedagogues is requested. The scenario development cycle ends when all proposed changes are implemented.

Technical features

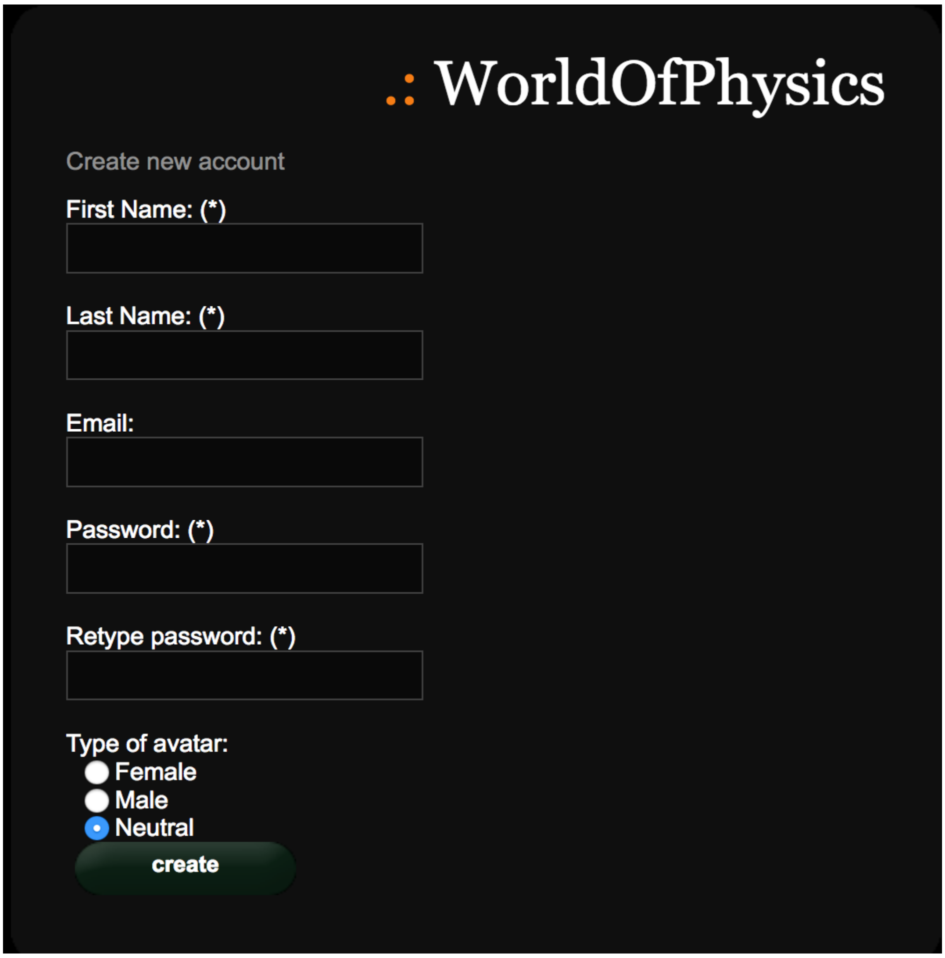
Creation of WOP account

To create the account, just connect to the link:

http://wopvr4stem.sch.gr:9000/wifi (the snapshot below)



By clicking on the "CREATE ACCOUNT" link located on the top right-hand side of the "Main Menu" section, you will be presented with the following form:



The data to be entered are the first name, the last name, the email address and a password; moreover, the user is asked to enter the gender of the avatar that will be created in the virtual world. By clicking the button “create”, the new account will be initialized (the username of the new account is given by "firstname lastname").

Installation and configuration of Firestorm Viewer

The virtual world of World of Physics is accessible by using a **viewer**. In the panorama of the software developed to be used as a viewer for 3D virtual worlds, "Firestorm Viewer" was chosen to meet the needs of this project. Firestorm is an open source project developed by the group "Phoenix Firestorm Project" and is based on the code of Linden Lab (company that developed Second Life). Among the main features of Firestorm:

- Windows, Linux and Mac OS X operating system compliant,
- Simplicity and easy customization of the user interface,
- Speed of execution,
- Robustness.

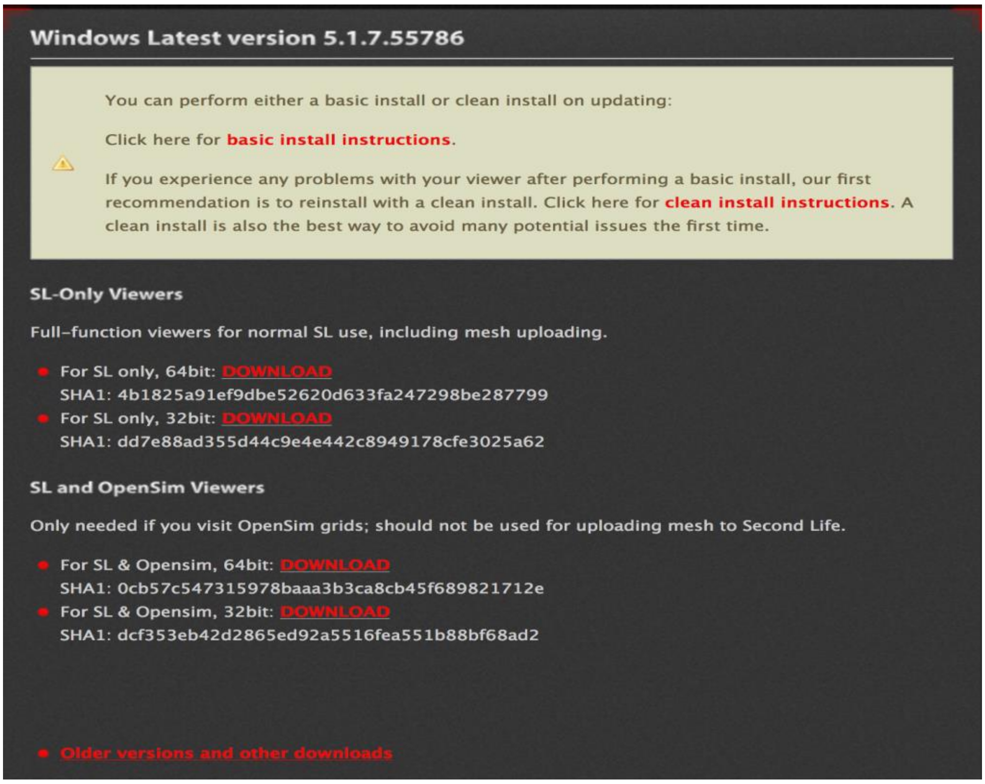
In the following chapter, the procedure for installing and configuring the WOP environment on the Firestorm Viewer will be presented.

Download Firestorm Viewer

The Firestorm Viewer program can be downloaded from:

http://www.firestormviewer.org/downloads/

By clicking on the icon of the corresponding operating system, the page for downloading the program is opened (see the next snapshot of the page to download the Window version):



Please note the SL & Opensim versions.

Windows Installation

Start the downloaded installation program. The 32-bit installer will offer you the possibility to change the destination directory. The 64-bit installer shows the destination when you click the Options button. The installer will create a shortcut icon on the desktop.

Note: The 32-bit installer offers an option to start the Viewer when finished: please choose No. Choosing Yes tends to cause problems for some people and to crash the Viewer.

MAC Installation

Find the *.dmg* file you just downloaded and double-click to start it. Then drag the Firestorm app icon into the Applications folder. More detailed instructions can be found here:

http://www.ofzenandcomputing.com/how-to-install-dmg-files-mac/

Note: Apple Gatekeeper software may initially prevent the Viewer from opening depending on the Gatekeeper settings. If it does, there is an easy way to change it (see the instructions "How to open an app from an unidentified developer" from this page https://support.apple.com/en-us/HT202491).

Once you allow Firestorm to open using this method, Gatekeeper will not ask again on subsequent launches (until you reinstall Firestorm again).

Linux Installation

Extract the downloaded *tar.bz2* or *tar.xz* file into any directory and run the firestorm script inside that directory to start it.

If you are installing it on a 64-bit Linux system, you will need to install some 32-bit libraries. Refer to the following page for indications on the required compatibility libraries:

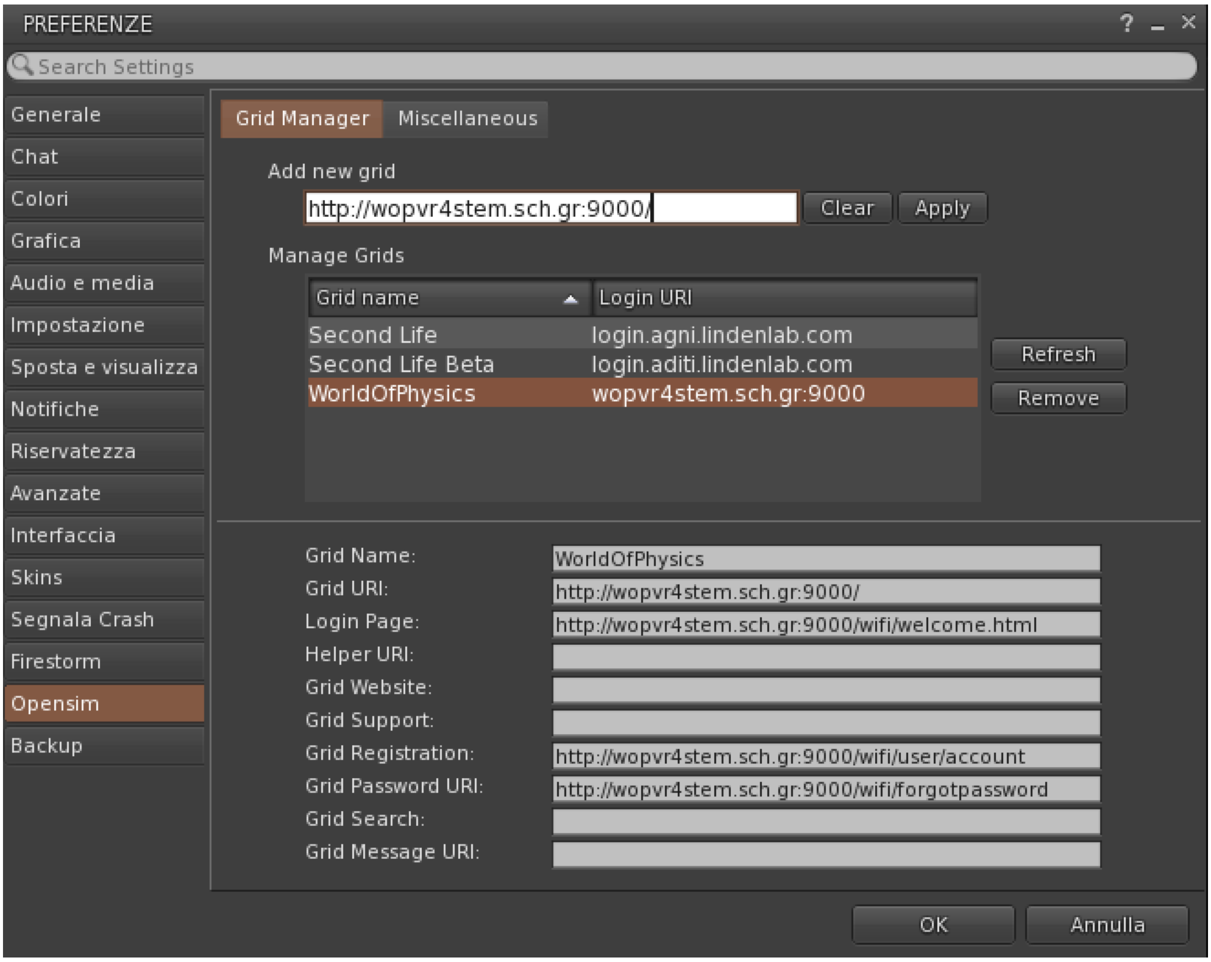
https://wiki.phoenixviewer.com/32-bit_viewer_in_64-bit_linux

If you use Nautilus File Manager and double-click the firestorm launch script, the script opens in an editor, you will need to change the way Nautilus handles the scripts.

Firestorm configuration for WOP

Once you have downloaded, installed and started the Firestorm Viewer, you need to add some information to configure the WOP environment. Click on the Viewer -> Preferences -> Open Sim menu and add a new grid with the following address:

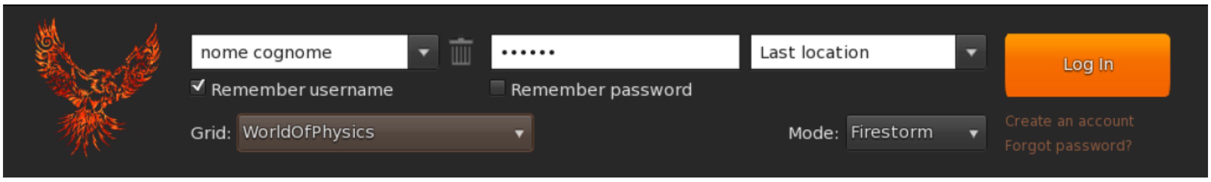
http://wopvr4stem.sch.gr:9000, as showed in the following snapshot:



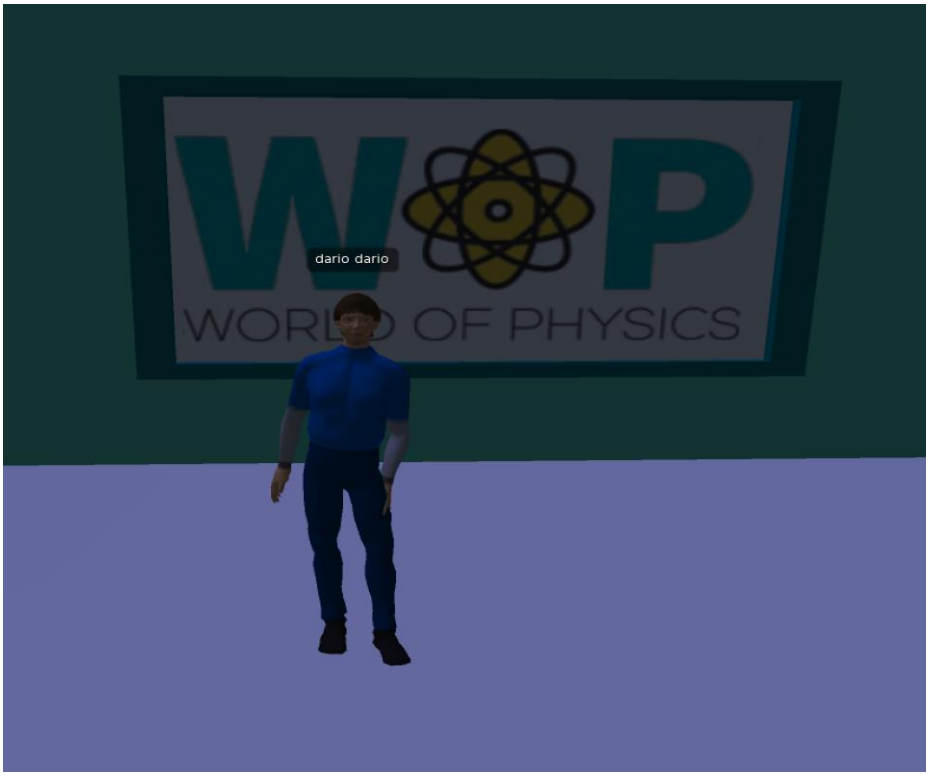
All configuration information will then be automatically loaded.

Access to the 3D WOP

To access the 3D environment of WOP, just open the Firestorm Viewer, and fill the lower section of the main screen (see following snapshot).



In the username field, you must enter the firstname and lastname chosen during registration of the account and in the password field, the chosen password. Finally in the combobox containing the GRID you have to select the GRID **World Of Physics** and press the "**Log In**" button.

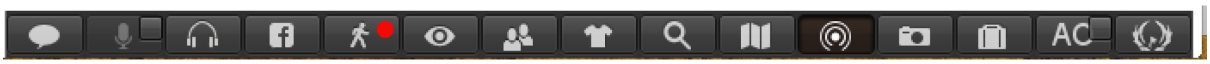


Basic Controls

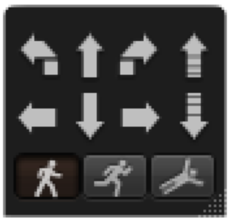
The basic functions of the viewer in order to enable the interaction of the Avatar with the 3D world, are detailed below.

Movement Controls and camera controls

The menu bar of the Firestorm Viewer is shown in the next figure:



By clicking on the icon marked with the red dot, a small window will be opened, with the movement control (see the figure below).



The window can be dragged to any area of the screen by selecting it with the left mouse button and dragging it where desired.

By clicking on the arrows of the control window with the mouse, you can move the avatar to the right, left, forward and back. You can also turn it to the right, to the left or to make it jump and lower.

In the window, there are 3 special keys that depict a man walking, running or flying. By clicking on these buttons, the avatar will perform the selected action. In addition to the movement window, the keyboard also gives the opportunity to move. Below are the details of the keys:

Key	**Motion**	**Equivalent**
W	Forward	Up Arrow
A	Turn Left	Left Arrow
Shift-A	Move Left	Shift-Left Arrow
S	Back	Down Arrow
D	Turn Right	Right Arrow
Shift-D	Move Right	Shift-Right Arrow
E	Jump	PgUp
C	Go Down	PgDn
F	Fly	Home

To enable the stroke, it is also possible to press the CTRL-R key. To go back to walking, just press CTRL-R again.

The mouse can be used to change the point at which your avatar looks. Shift your mouse in an area of the virtual world the avatar's gaze will be directed towards that area and consequently also to the scene.

Overview of the WOP virtual environment

The main Areas

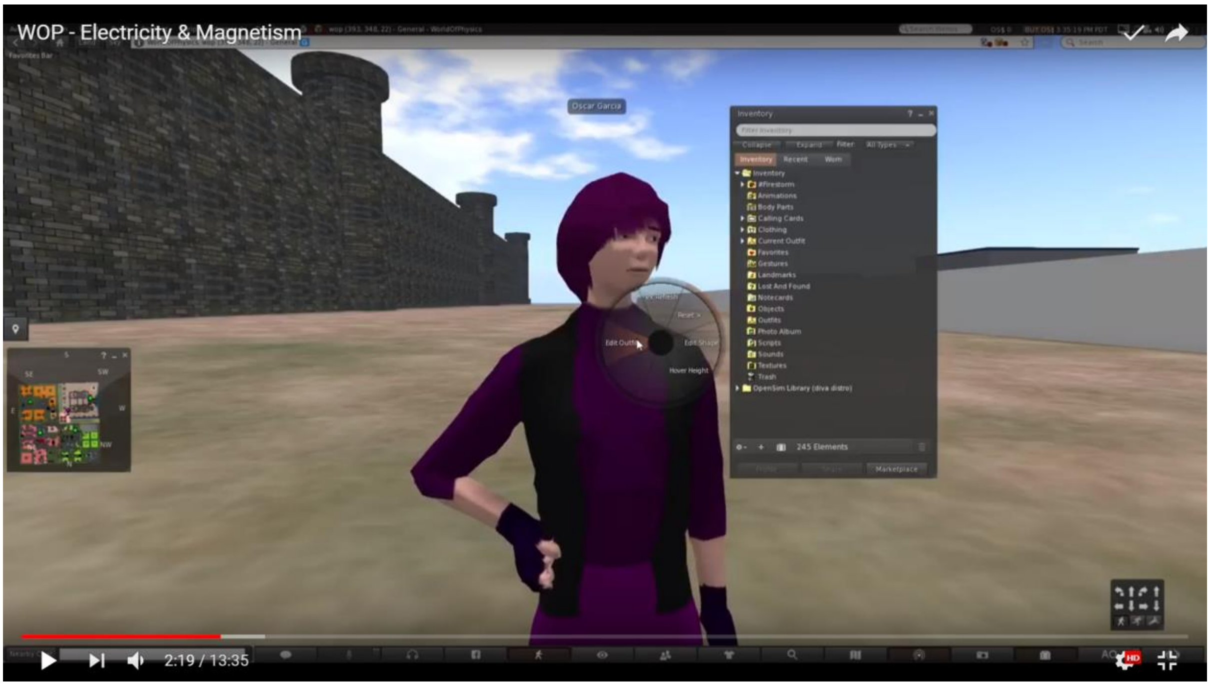
The WOP world has been created as a land divided into 3 main Areas (Mechanics, Structure of matter, Electricity and magnetism). Each area has been designed to give students the opportunity to discover, explore and learn physics concepts in a fun and entertaining ways. The table below shows the areas developed and the physics contents.

Area 1 - Mechanics	**Area 2 - Structure of matter**	**Area 3 - Electricity and magnetism**
Linear motion (velocity, acceleration, vectors and scalars)	The electron	Electrification by contact and induction
Newton's laws of motion (force, momentum)	Thermionic emission	Distribution of charge on conductors
Gravity	Photoelectric emission	Force between charges
Conservation of momentum	X-rays	Electric fields, Electric energy, Potential difference
Moment – conditions for equilibrium	Structure of the atom	Capacitor and capacitance
Work	Structure of the nucleus	Electric sources and Electric current
Energy (conversion, principle of conservation, power)	Radioactivity, Ionising radiation and health hazards	Resistance and Effect of electric current
Oscillations and waves	Nuclear energy	Magnetic fields and current in a magnetic field
Gases (density and pressure)	Quarks and the Standard Model	Electromagnetic induction
		Light

For each of these topics, a learning scenario has been developed. Each scenario includes one or more virtual laboratories in which the student can train his knowledge and skills through the IBSE experiential model.

Virtual Labs in the WOP virtual environment

The virtual laboratories present in different areas of the WOP virtual environment will be described below. For each laboratory are specified: the educational goal, the prerequisites to face the educational activity and the interactions of the avatar with the environment. For a detailed overview of the activity, refer to the videos posted on Youtube and which will be proposed below for each area.



Area 1: Mechanics

Below the link to a demo video showing the laboratories from the “mechanics” area:

https://www.youtube.com/watch?v=5pYu51bG4CM

Linear Motion

The **learning objectives** are:

- scalar quantities of “time” and “distance” and their units of measurement.
- vector quantity of “displacement” (change in position) and its difference from “distance”.
- “Speed” and “velocity”: definition, formulas and unit of measurement. Motion with constant velocity.
- “Acceleration”: motion with changing speed and average speed.

The prerequisites for successfully completing this scenario are:

- familiarity with the following Physics topics: Vectors, Scalars, Units, Measurement and Motion.
- a basic experience level in 3DVW environments.
- completion of other scenarios before playing this scenario.

Below is the list of learning activities and materials available in the laboratory.

NAME	**SHORT DESCRIPTION**	**TYPE**
Elderly couple	Elderly couple walking	*NPC*
Teenage boys	A young boy riding his skateboard along with another young boy (friends) on roller blades	*NPC*
Lady jogging	A young woman jogging	*NPC*
Digital clock	A digital clock in the park showing seconds	*Object*
A child with a toy car and a small oval track	The child controls a toy car in a small oval track.	*NPC and Object*
Smartphone/ Tablet	Smartphone/Tablet	*Presentation*
Quiz	A quiz on the theory of velocity, speed and acceleration	*Assessment*

The avatar visits the park and sits on the bench with his/her smartphone/tablet. While reading a presentation about theory on Velocity etc., the following NPCs and objects pass by him/her: two young boys on rollerblades and skateboards, an elderly couple walking, a lady jogging and a child playing with a toy car. The objective of the scenario is to closely observe the motion of these NPCs and objects and later fill a quiz that will ask questions about their motion. The quiz will be prompted to the user towards the end of the scenario.

The Newton' laws

Learning objectives

- Newton's 1st law. Mass, inertia and net force.
- Newton's 2nd law. The force causes acceleration. Mass resistance. Friction resistance.
- Newton's 3rd law. Action and reaction.

The prerequisites for successfully completing this scenario are:

- familiarity with the following Physics topics: Vectors, Scalars, Units, Measurement and Motion.
- basic experience level in 3DVW environments.

The location for this scenario is a large room. The student's avatar will do experiments for the 1st and 3rd law of motion and play several simulations for the 2nd law of motion. For each experiment and simulation, the avatar will be required to view a presentation, then do the experiment or play the simulation and finally complete a quiz. By successfully completing the tasks and quiz for each of the laws, the avatar will receive a piece of the puzzle for the International Space Station puzzle (see the figure below).

There needs to be a wall within this setting, where the puzzle will be put together. The student will need all 3 pieces (1 for each law), in order to complete the puzzle and therefore receive a reward and progress to the next subtopic.

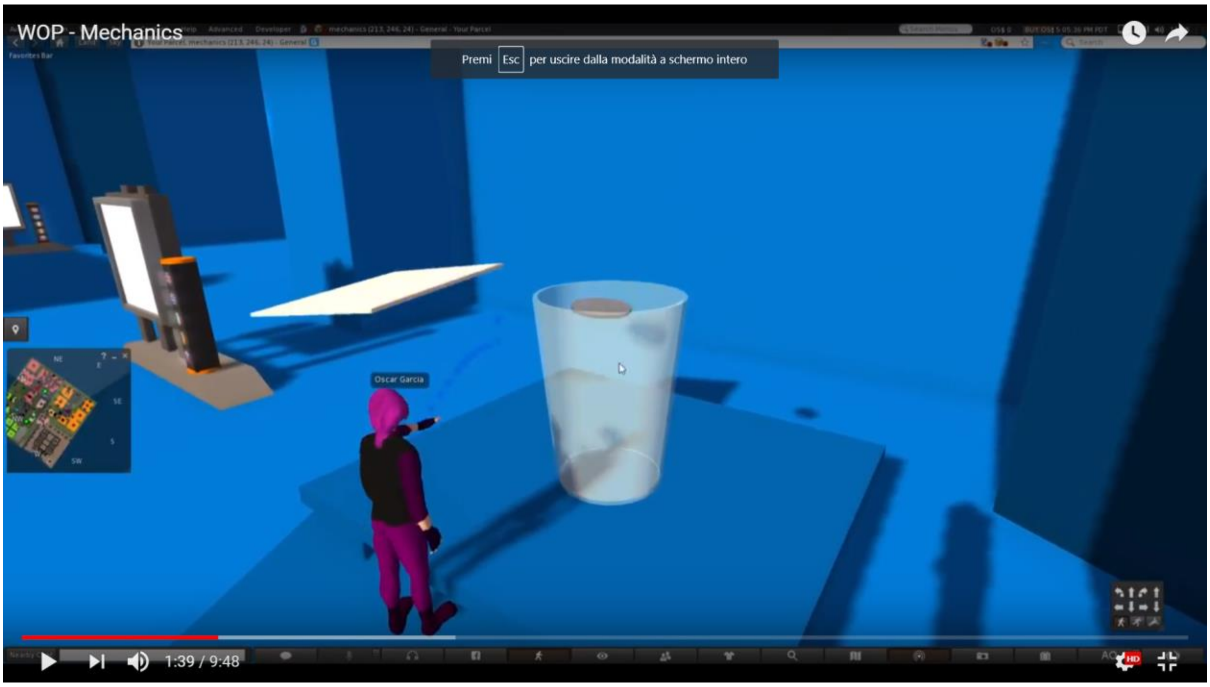
Below, there is the list of learning activities and materials available in the laboratory.

NAME	SHORT DESCRIPTION	TYPE
1st Law	Short presentation of this law	*Presentation*
Experiment on inertia	Coin and the glass experiment	*3D Activity*
Quiz	A quiz on the 1st law	*Assessment*
2nd Law	Short presentation of this law	*Presentation*
Testing interaction	2D simulations – the effects of forces	*2D Activity*
Quiz	A quiz on the 2nd law	*Assessment*
3rd Law	Short presentation of this law	*Presentation*
Experiment on action-reaction	Metal sled that slides easily experiment.	*3D Activity*
Quiz	A quiz on the 3rd law	Quiz

The avatar will be informed through a notecard given to him that he needs to visit the Sir Isaac Newton's room and build the International Space Station puzzle.

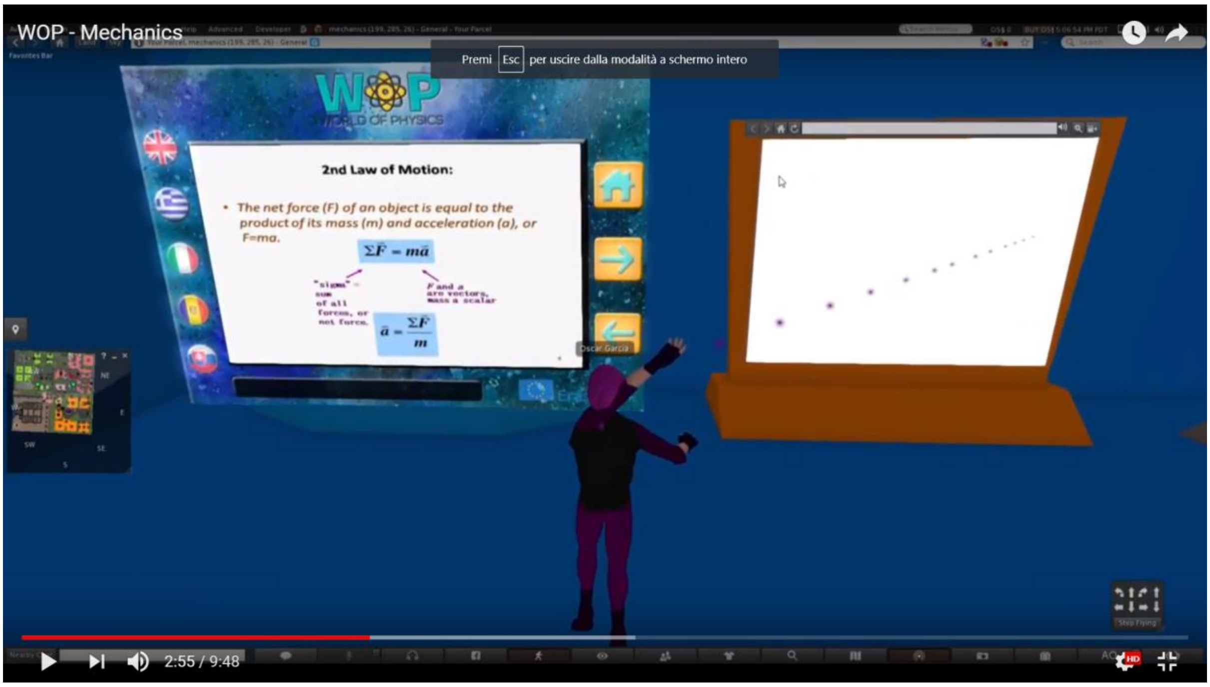
In the one corners of the Sir Isaac Newton's room, there is a flag with "1st Law" written on it. The avatar will need to view the presentation of the 1st law before doing the experiment.

The experiment for the 1st Law is the **Coin Drop Experiment**.



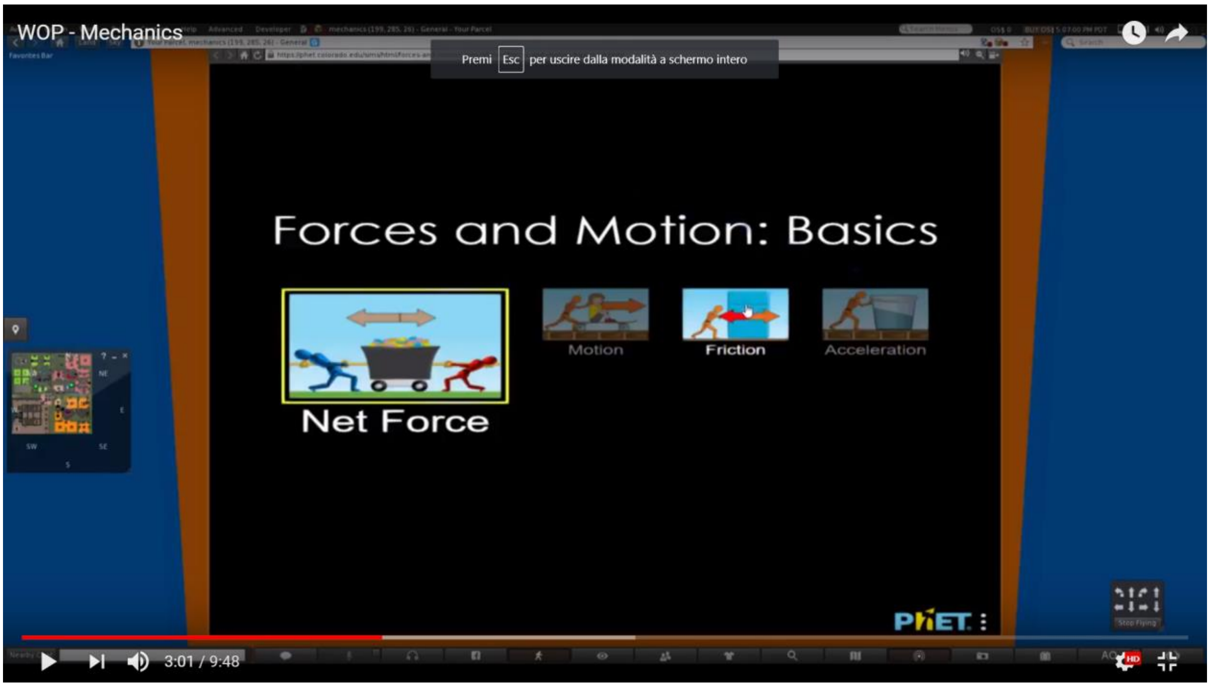
Once the avatar completes the experiment and passes the quiz on the 1st law, he/she receives the first piece of the puzzle. Then, the avatar will then place the piece on the wall where the puzzle will be put together. When the piece of the puzzle fits into the overall puzzle, the avatar receives a message with the indication to proceed and complete the activities for the 2nd Law in order to get the next piece of the puzzle.

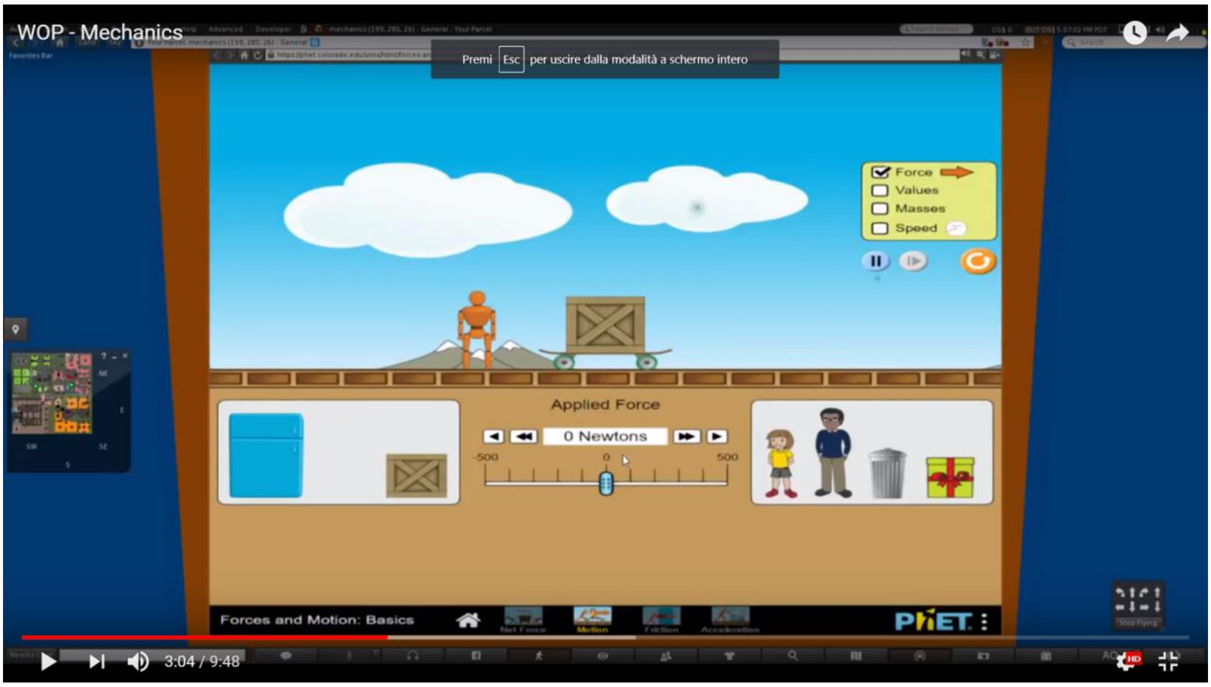
In another corner of the Sir Isaac Newton's room, there is a flag that has "**2nd Law**" written on it. The avatar will need to view the presentation on the 2nd Law before playing the simulations.



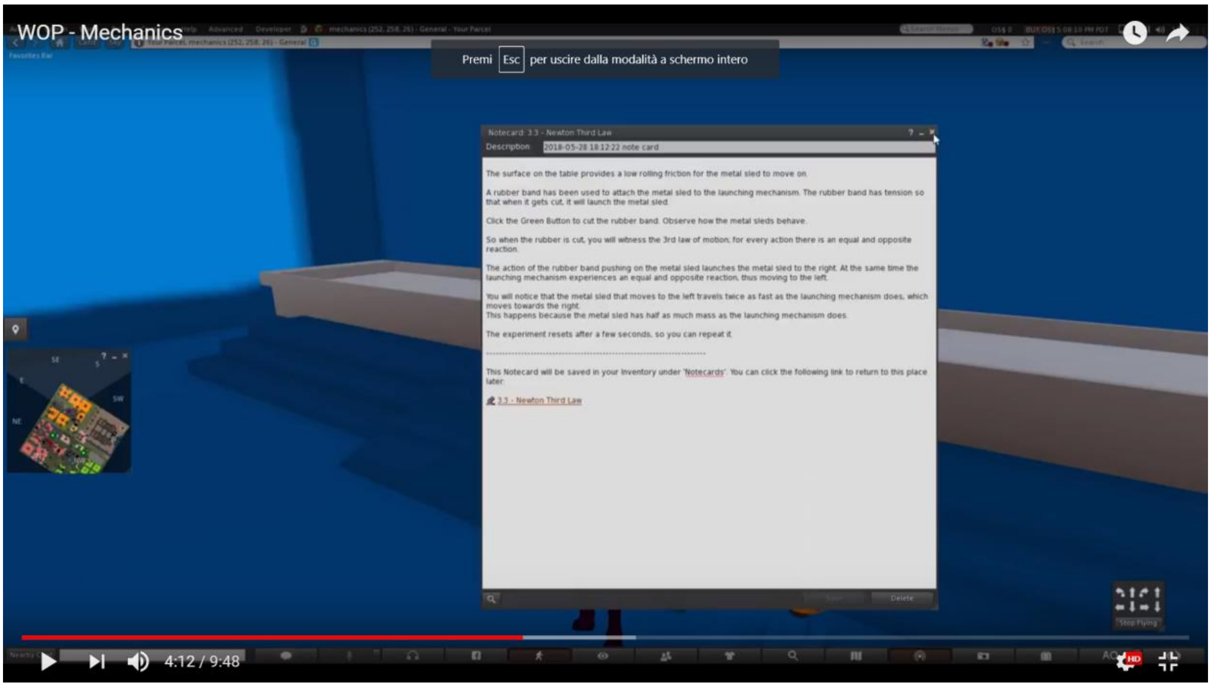
There are 4 simulations the avatar needs to play:

1. **Net force;**
2. **Motion;**
3. **Friction;**
4. **Acceleration.**

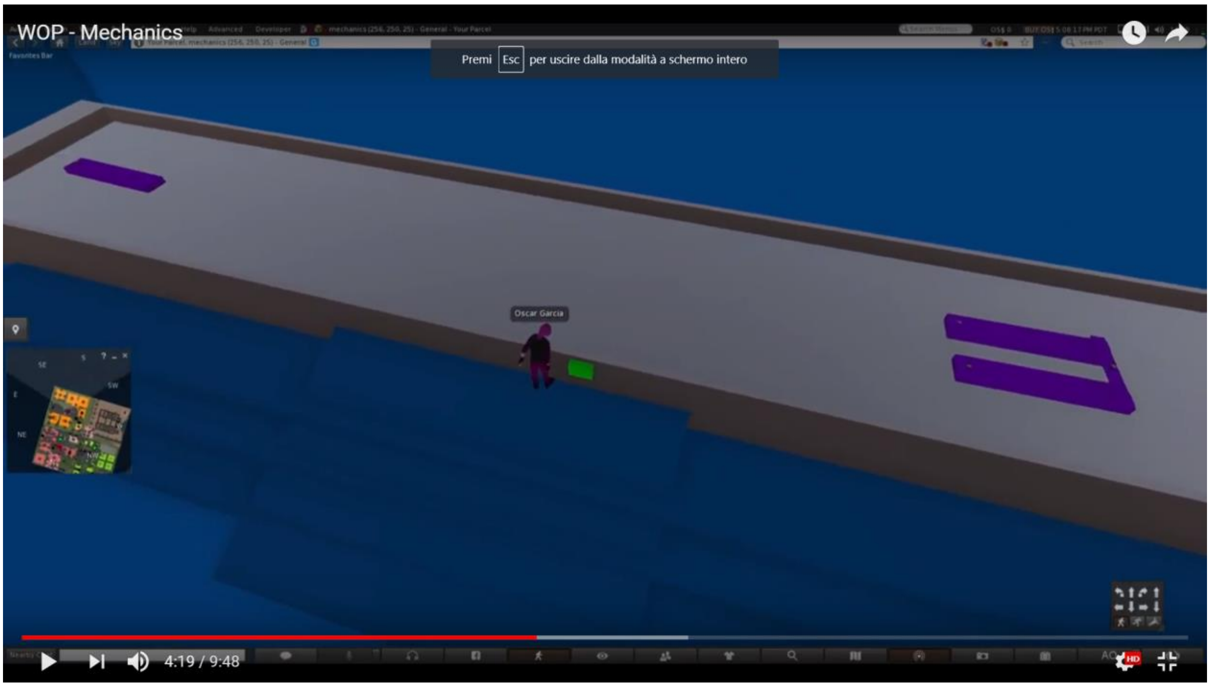




When the piece of the puzzle fits into the overall puzzle, the avatar receives a message to proceed and complete the activities for the 3rd Law, in order to get the final piece of the puzzle. The avatar will need to view the presentation on the **3rd Law** before doing the experiment.



The experiment for the **3rd Law** is the **Metal sled slide**.



Area 2: Structure of matter

The following link contains a demo video, showing the laboratories from the area “Structure of matter”.

https://www.youtube.com/watch?v=tS-FJH7tAbo

Radioactivity, ionizing radiation and health risks

The following information describes, as an example, the scenario developed for the topic concerning "**Radioactivity, ionizing radiation and health risks**". In this scenario, students learn about radioactivity, the nature of radiation and health risks from radiation exposure. The list of learning objectives of this scenario are:

- the nature of radioactivity;
- the process of decay of radioactivity;
- differences in radioactive emissions;

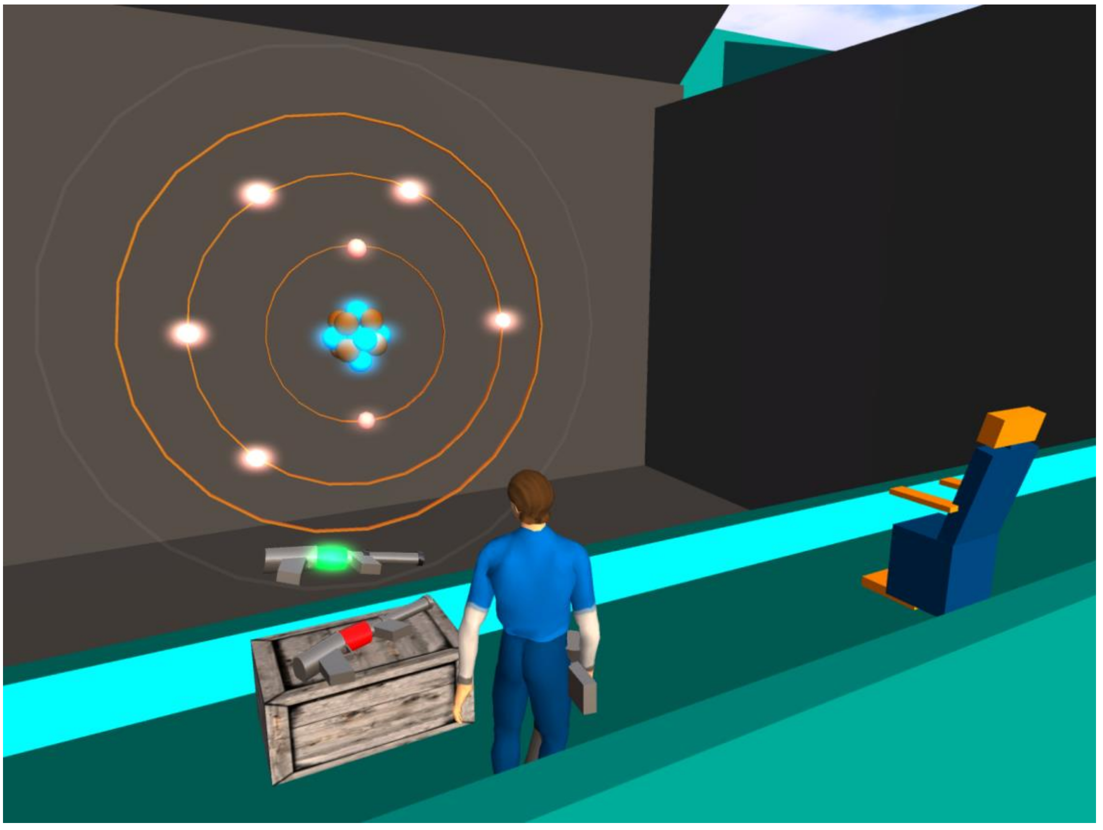
- what is radiation;
- how to discriminate between ionizing radiation and non-ionizing radiation;
- the impact of ionizing radiation on the molecular structure;
- Knowledge of potential health risks from radiation exposure.

The prerequisite for successfully completing this scenario is a good understanding of the use of the viewer for the 3D virtual world and the knowledge of the topic "**Structure of the Atom**".

The virtual world offers two different learning paths: a guided learning path and an open learning path. In the guided learning path, students must follow the sequence, marked by arrows, of the learning resources established in the open learning path. Students are free to explore and experience the world as they prefer.

When the avatar is teleported to the radioactivity area, a desolated landscape is shown: bare trees, no trace of life, puddles of water with tanks marked with the symbol of radioactivity. The arrows are guiding the avatar through this landscape and how to access the educational resources. In this section, there is a very dangerous area marked by radioactivity symbols. At the entrance to this area, there is a non-player character that informs the avatar about the danger of the area and the health risks the avatar is exposed to. When the avatar approaches a radioactive object, the health status indicator will begin to decrease depending on the nature and intensity of the radiation and as a result, the avatar's posture will change. When the health status decreases to zero, the avatar will fall to the ground and an alarm will indicate that the radioactivity has killed him.

In the following area, the student can deal with the topic of "**Ionizing and non-ionizing radiation**" by accessing a laboratory where the avatar will find a cannon and an atom with the electrons that revolve around it. The avatar will be asked to take a radiation cannon. The cannon is equipped with a potentiometer that allows the wavelength change of the emitted radiation. When the avatar clicks the "fire" button, a radiation (in the form of a sine wave with a specific wavelength) will be fired and will hit the atom. The electrons of the atom in the outer orbit will be excited and will turn faster. If the emitted radiation is in the ionizing radiation range, some electrons of the outer orbital will be freed from the atom and turned into an ion.



Teachers can make a virtual visit to the laboratory at the following link:

https://www.youtube.com/watch?v=tS-FJH7tAbo

Structure of the Atom

The learning objectives are:

- Atoms as elements of matter;
- Discovery of the structure of atom (Cathode-ray tube, Rutherford's experiment);
- Bohr model of the atom, the elements and basic properties of the atom;
- Atomic number and mass number of a chemical element.

Students who use this laboratory must have knowledge on the topic "**Structure of the Atom**".

The location for this scenario will be in the rooms of a lab and then will be a travel into the atom by using a Pico rocket.

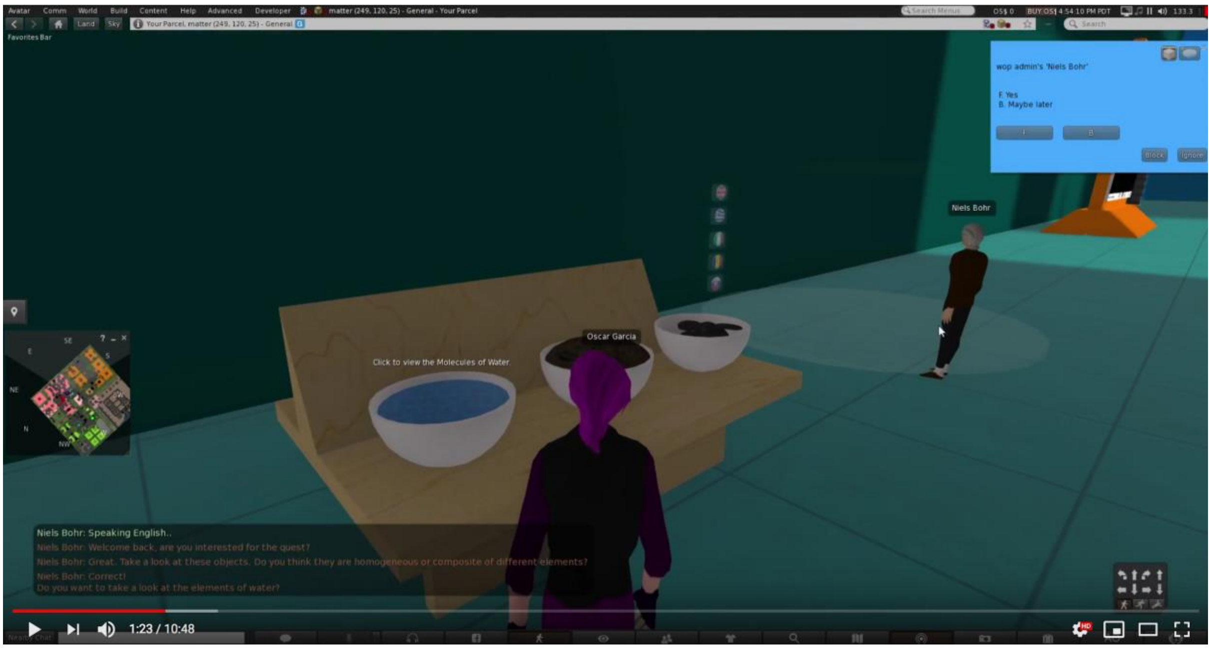
Below there is a list of the learning activities and materials available in the laboratory:

NAME	SHORT DESCRIPTION	TYPE
The atom	A short historical introduction on the discovery of the atomic structure and the Bohr model.	*Presentation*
Rutherford's experiment	Rutherford's experiment	*Multimedia*
Atomic Models	Experimentation with the different atomic model.	*Multimedia*
Traveling into the microscopic world	A trip into the microscopic world of atoms and their structure	*3D Activity*
Bohr	He will assist the student in the 3D activity.	*NPC*

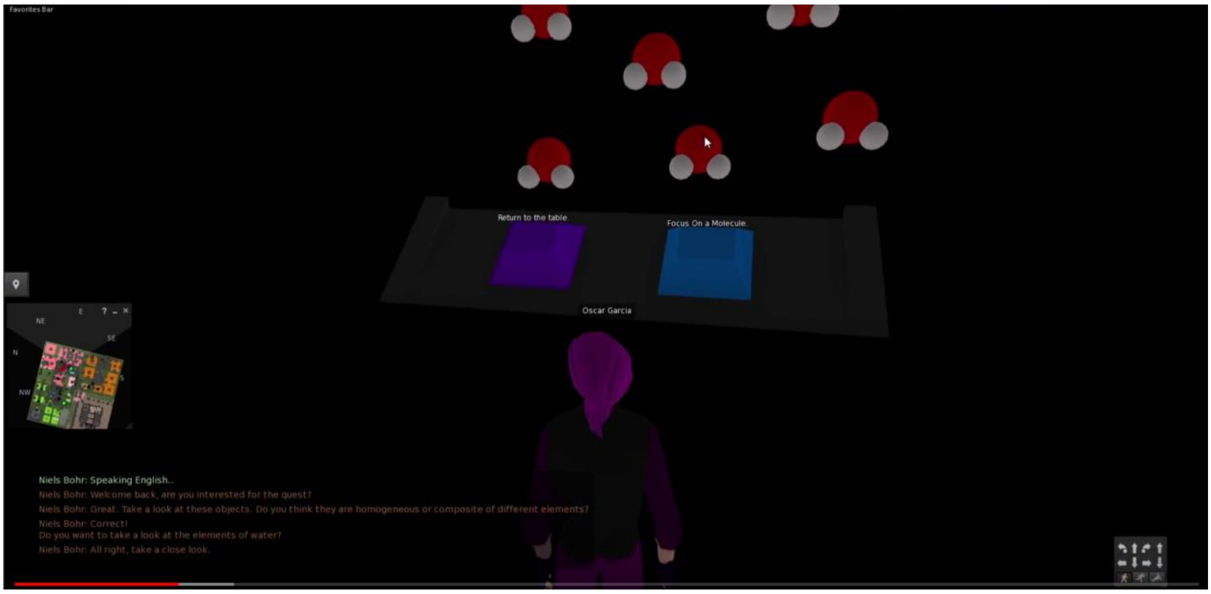
The student will watch the presentation and optionally explore the multimedia applications. Then he/she will be assisted by the NPC to explore the microscopic world in the 3D activity.

Niels Bohr NPC will guide student throw the study of the molecule of water.

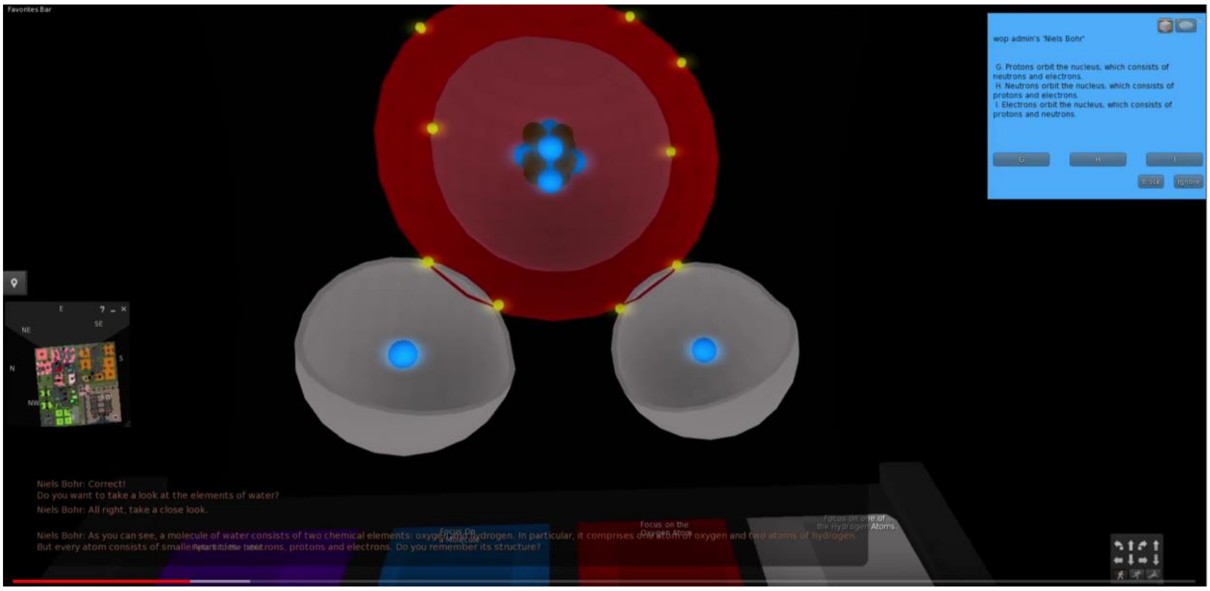
On the table, the student can find some elements. One of them is the water.



By clicking in the water element, the avatar will travel inside the molecule of water.



By clicking on the molecule of water, the avatar can go deeper at atomic level.



Area 3: Electricity and magnetism

Below there is link with a demo video, showing the laboratories in the area "Electricity and magnetism":

https://www.youtube.com/watch?v=ol7RqElkrNQ

Contact Electrification

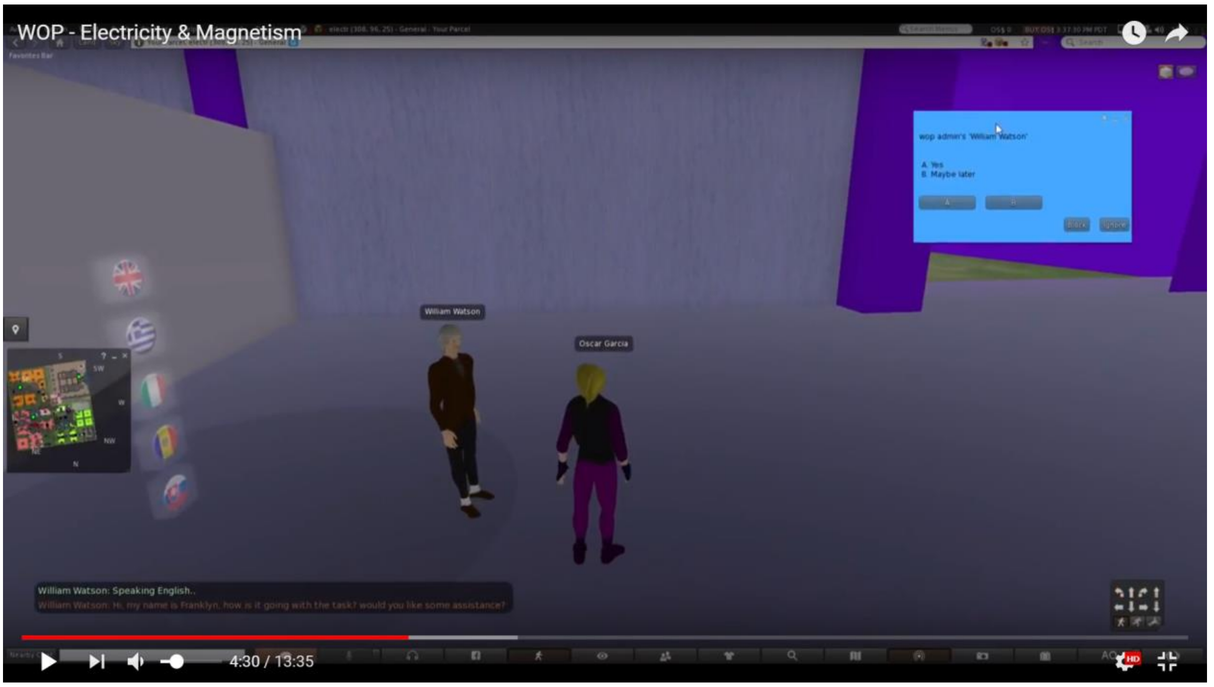
The learning objectives of this area are:

- Phenomena of electrification at the macroscopic level;
- Allocation of positive and negative charges in electrification by friction (the effect of different affinity for electrons);
- Balance of charges in electrification by conduction (in relation to the law of conservation of charge).

This is the first subtopic from the general topic "**Electricity and Magnetism**". Thus, theoretical prerequisites are going to be included in particular information about the microscopic elements of matter (topic "**Structure of matter**").

The **learning activities** available in this laboratory are the following:

NAME	SHORT DESCRIPTION	TYPE
Electrification by friction	General information about the atomic particles, the force between the electric charges and introduction to electrification by friction.	*Presentation (1)*
Electrification by conduction	Information about the law of conservation of charge and the procedure of electrification by conduction.	*Presentation (2)*
Electrification by friction and by conduction	Objects of different material are electrified by friction, compared regarding their affinity for electrons, attract light objects and charge other objects by conduction.	*3D Activity*
William Watson	The character will assist the student to accomplish the activity.	*NPC*



After watching the first presentation, the students will take a couple of the objects placed on the counters and rub them with each other, in order to electrify them (electric charges transfer from one to another). They will sort them according to their affinity for electrons and use them to attract light objects. The students will then watch the second presentation and use some of the charged objects to charge by conduction some other neutral objects, with a defined kind and amount of charge.

Inducation Electrification

Using a charged glass rod (found in the activity of the subtopic "**Electrification by friction and by conduction**"), the students charge by conduction pairs of metal and plastic objects.

The students touch the objects with a charged glass rod. When they touch a metal object (a conductor), the electric charges distribute evenly on its volume (according to each shape).

When they touch a plastic object (an insulator), the excess charge remains at the initial location of charging.


WOP - Electricity & Magnetism
5:31 / 13:35

Charging by friction

The avatar will pick two objects at a time and rub them together.

When objects of different material are rubbed together, electrons transfer from one to the other. Electrons will be represented with the symbol “-”. The object which accepts the electrons is charged negatively (signs of the symbol “-” appear on its surface), while the object which offers the electrons is positively charged (signs of the symbol “+” appear on its surface).

You can see a similar simulation at the link mentioned in the References.

An indicative distribution of charge for each couple of objects is described in the table below:

	Rabbit	Glass rod	Wool	Silk cloth	Amber stone	Rubber rod
Rabbit	0	2	4	8	10	12
Glass rod	2	0	2	6	8	10
Wool	4	2	0	4	6	8
Cat	6	4	2	2	4	6
Silk cloth	8	6	4	0	2	4
Amber stone	10	8	6	2	0	2
Rubber rod	12	10	8	4	2	0

After the electrification by friction is completed, the charge of each object must be identifiable either with the continuous appearance of the charges on its surface or by the appearance of a label above it.

In the second case, the charges may become visible only during the activity and if the students wear special glasses.

For each couple of objects rubbed together, electrons are transferred to the one which is placed lower in the first column. The rest of the cells present the number of electron signs (“-”) which appear to transfer. Numbers are indicative and offer only a proportional representation of the phenomenon.

The students will then watch the second presentation and use some of the charged objects to charge by conduction some other neutral objects, with defined a kind and amount of charge.


WOP - Electricity & Magnetism
Premi Esc per uscire dalla modalità a schermo intero
ELECTRICITY AND MAGNETISM
Electrification
by conduction
Erasmus+
7:18 / 13:35

Charging by conduction

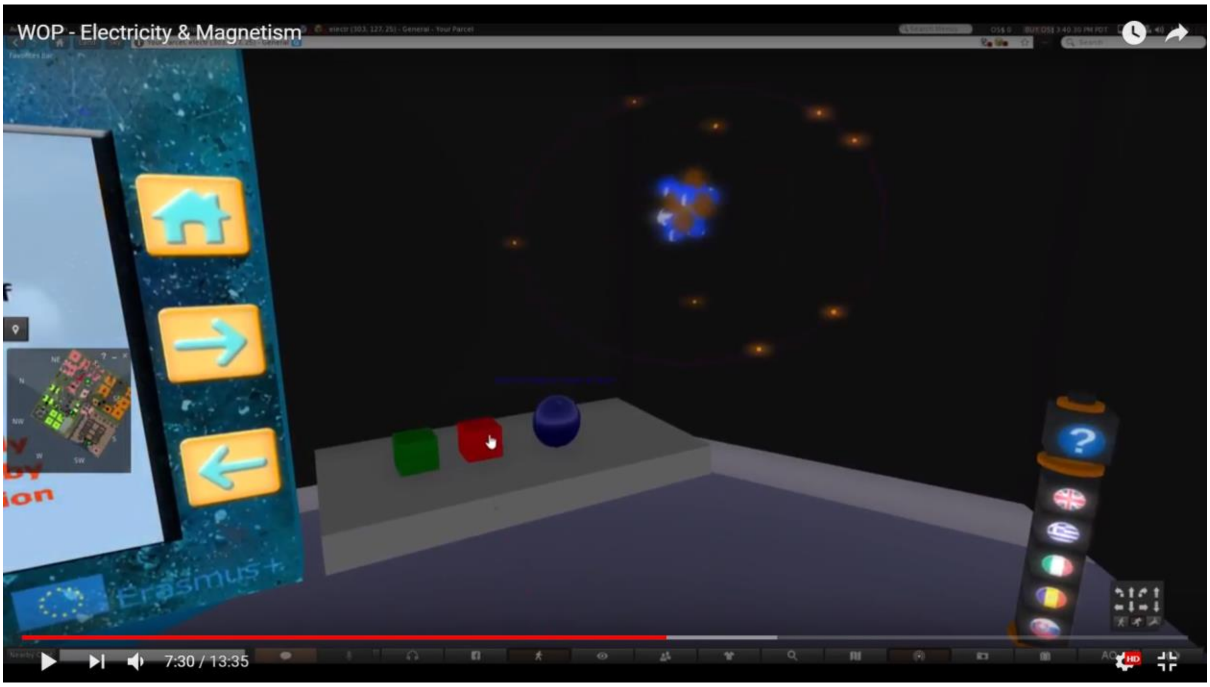
The student has to charge a neutral surface with defined kind and amount of charge. He takes a previously charged object (with the suitable kind of charge) and touches the neutral surface.

Electrons transfer from one object to the other until both objects carry the same amount of charge.

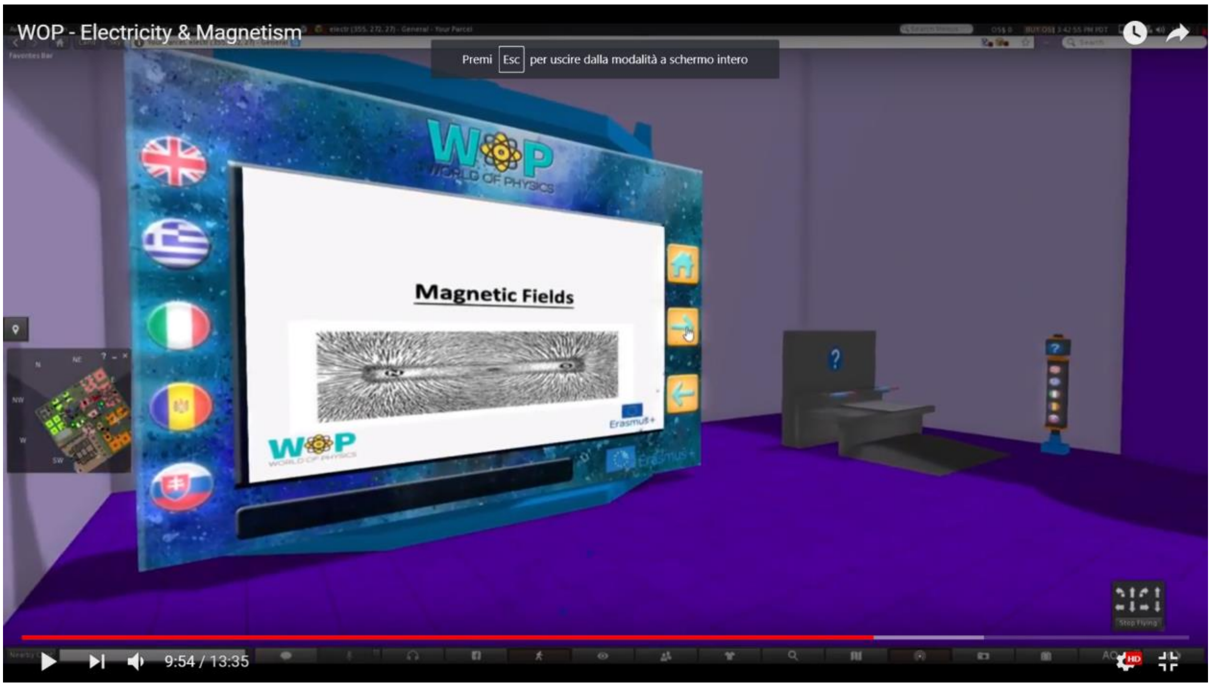
If the charge of the surface is less than the required he will have to use another charged object and repeat the procedure.

If it is more than the required amount, the student will have to use a charged object of opposite charge and repeat the procedure.

The student can further see the representation of the atom with the outer electron lost, when charging an element:



Magnetic fields and current in a magnetic field



The learning objectives are**:**

- Magnetic phenomena: the magnetic field of earth, the function of the compass, and the effect of a magnet on iron filings;
- Production of the magnetic field by moving charges;
- Charged particles moving in a magnetic field;;
- Current-carrying wire in a magnetic field.

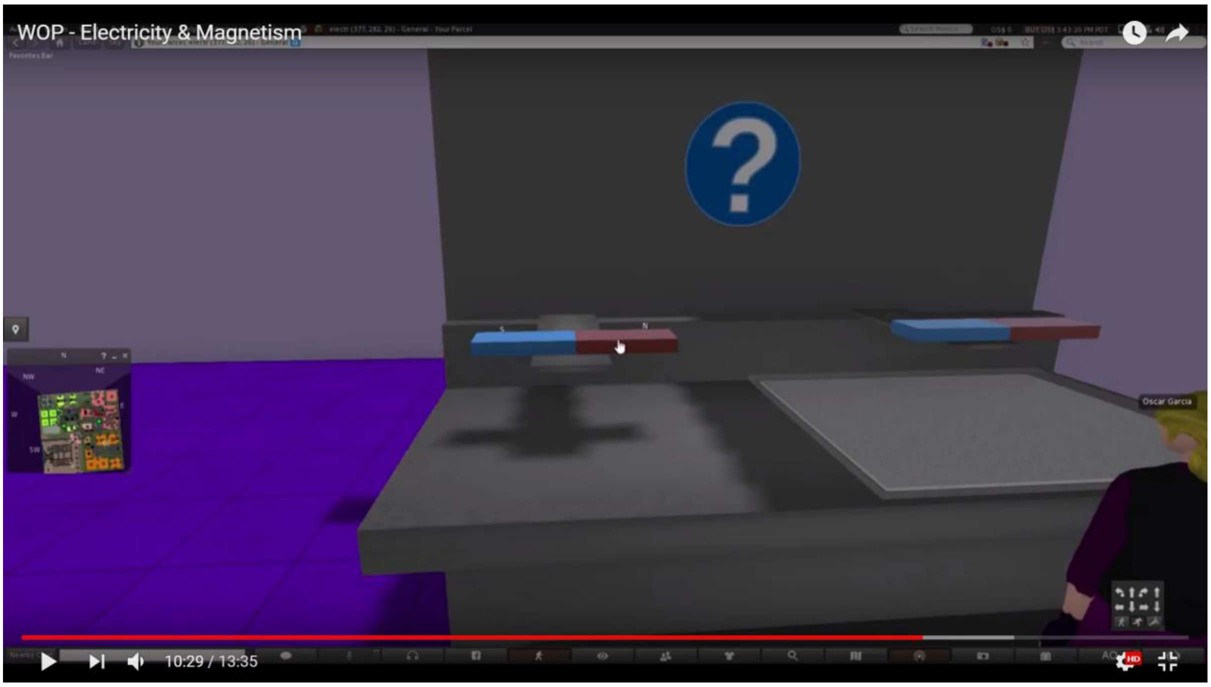
The prerequisite for successfully completing this laboratory are:

- Subtopics “Electric fields”, “Electric current & electric sources” and “Resistance & effects of the electric current”;
- Information about the Bohr model of the atom from the subtopic “Structure of the atom” (topic “Structure of matter”).

Below, there is the list of the learning activities available in this laboratory:

NAME	SHORT DESCRIPTION	TYPE
Magnetic phenomena	Magnetic phenomena: attraction of metals by magnet, the Earth's magnetic field and the function of the compass	*Presentation*
The effect of a magnet on iron filings	The student holds a bar magnet above a surface with iron filings and examines how they line up along the magnetic field lines	*3D Activity*
Magnetic field by moving charges	Representation of the magnetic field formed by moving charges and by the electric current	*Multimedia*
Moving charged particles in a magnetic field	The force exercised on moving charged particles and current-carrying wires within a magnetic field	*Presentation*
The Lorentz force	The force exercised on charged particles, which are moving (free or within a wire) in a magnetic field, changes according to the direction of their velocity	*3D Activity*

The student will watch the presentation about the magnetic phenomena and he will be assigned a task for the 3D activity. The activity will require him to examine the form of the magnetic field around a magnet, according to the placement of the iron filings. Then, by using the multimedia and information about the Bohr model of the atom, the student will have to find out how the magnet's field is formed by the polarization of its atoms.



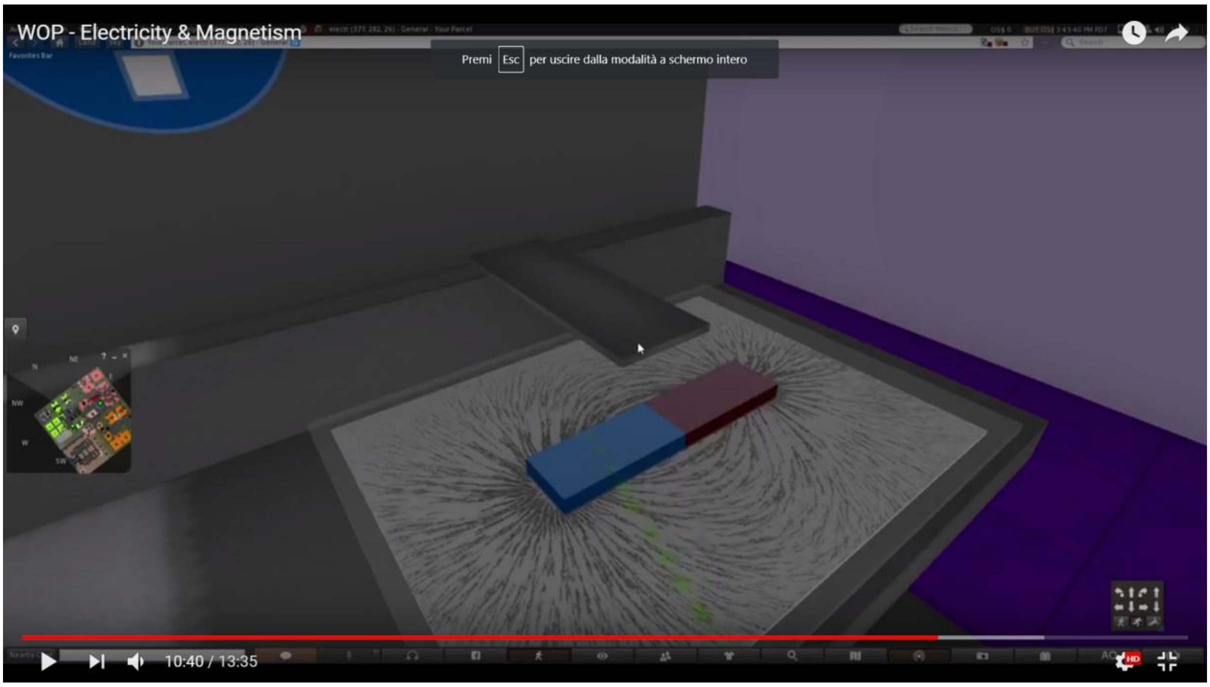
Iron filings are sprinkled uniformly on a surface and a thin transparent film is placed right above them. The student places a bar magnet on the film and the iron filings line up along the field lines. As the magnet is moved in several locations, the iron filings adjust accordingly.

The student examines how a compass is oriented along the field lines. Then the student uses a visual filter which reveals an augmented reality where the field lines and a sign for the magnet's poles appear.

More magnets can also be used in order, to examine their interaction and the corresponding changes in the field.

The transparent film must be firmly placed on the surface and at a very small distance above the filings. Due to the limitations of the 3D world environment, the "movement" of the magnet, the filings and the field lines, it should be probably reduced to a transposition within distinct locations (instead of a "continuous" movement that is usually represented in two dimensional simulation software, like Faraday's Electromagnetic Lab).

When the avatar places the compass aside to the magnet, the metal sheet will also line up along the field lines.



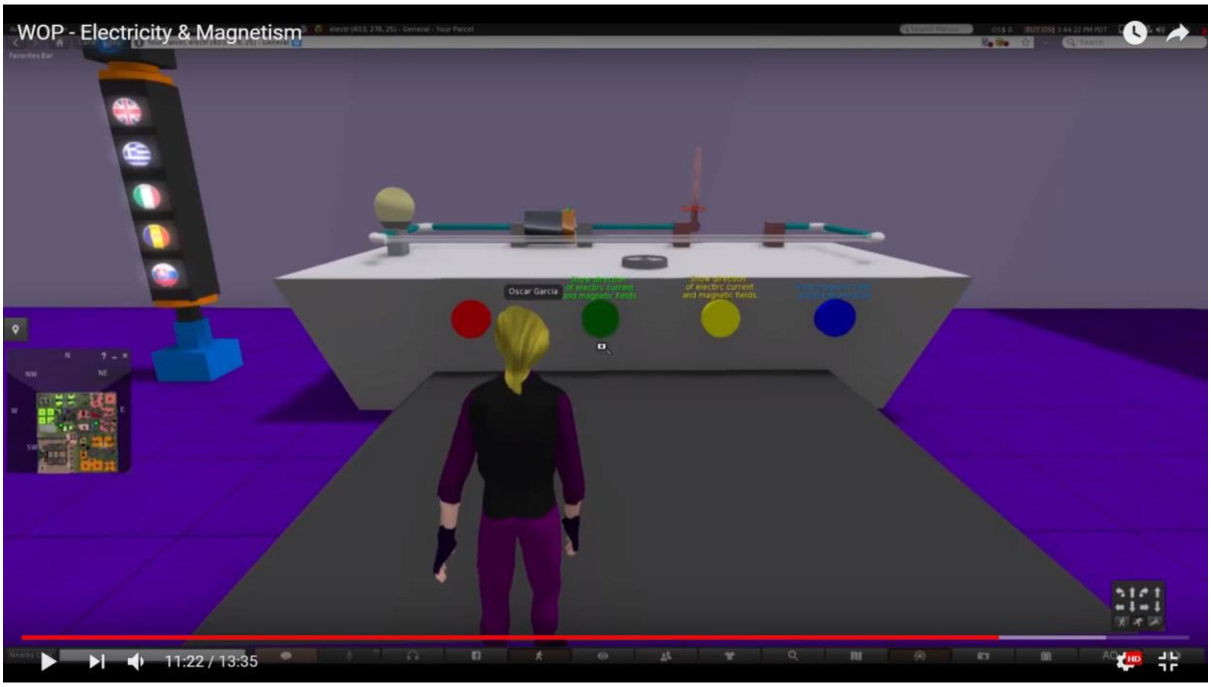
When the avatar wears his "Faraday glasses", the field lines will appear in 2D (or 3D, if possible). A simple sign for the magnet's poles will appear (as well as on the compass).

Following the learning objectives, the students are expected to be able to:

- Describe how a magnetized object is oriented along the magnetic field lines;
- Recognize that a compass is a magnet and describe how it is oriented along the field lines;
- Describe the interaction between magnets, in relation with their poles.

Force on a Charged Particle Moving in a Magnetic Field

Firstly, the electric circuit is placed on the table.

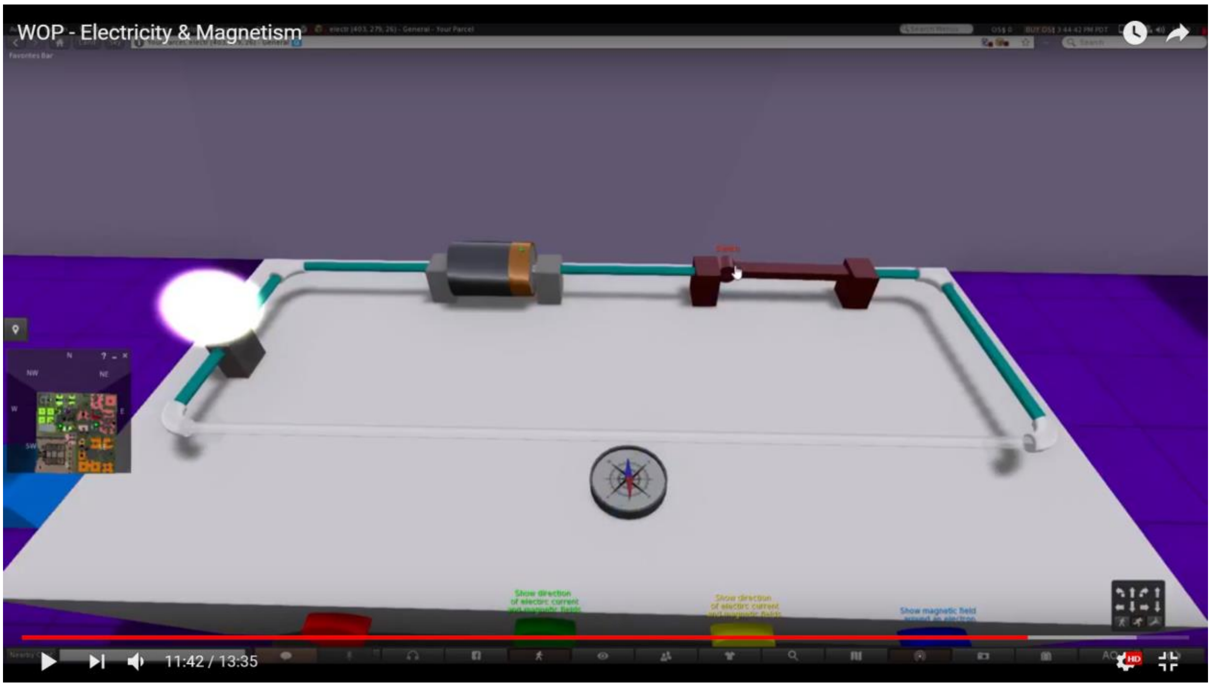


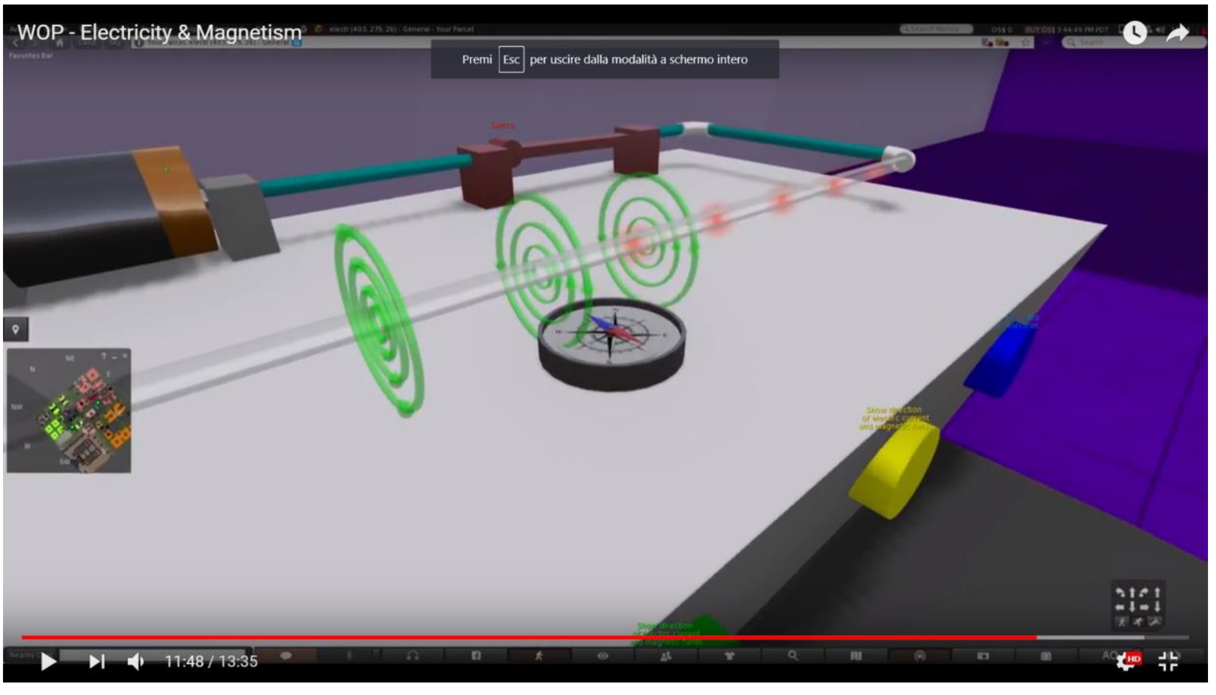
The student closes the circuit by using the switch. The animation of electrons shows how the electric current flows.

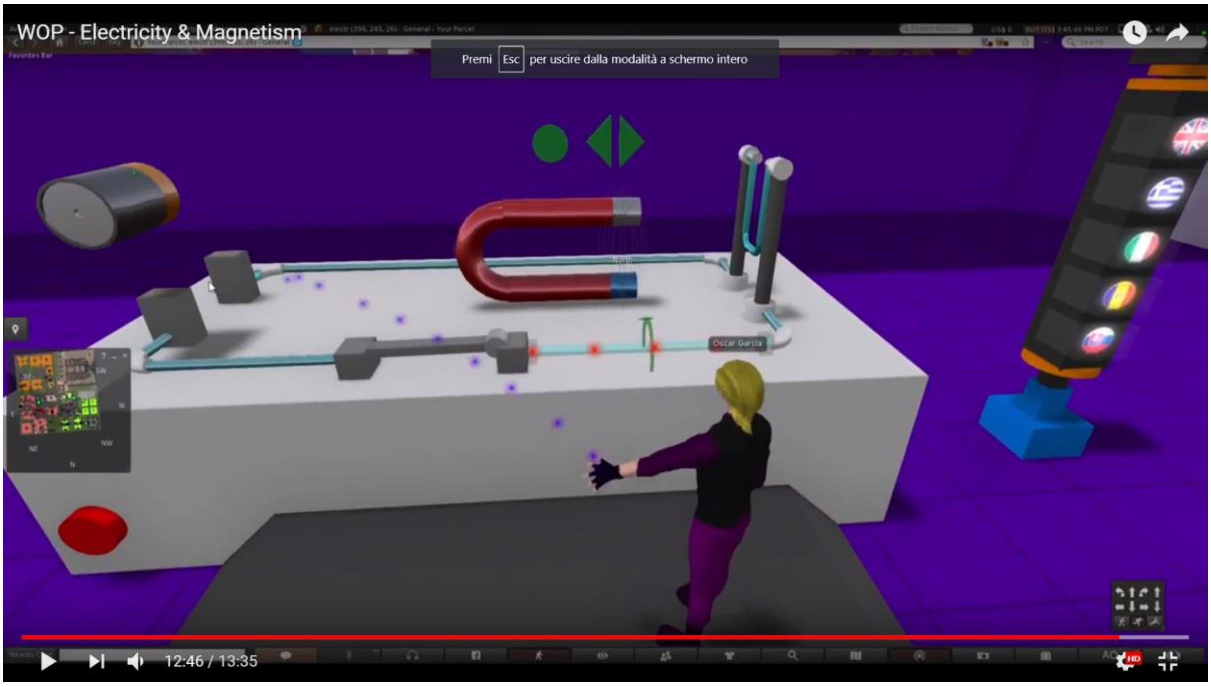
Next, the student interrupts the circuit and turns on the battery. The animation of the electrons shows that the electric current is going on the opposite direction. The wire placed on the clamp holder has no motion.

Next, the student places the U-shape magnet in the area of the electric circuit. Based on the direction of the Lorentz' force, the wire placed at the clamp holder will move.

The following pictures show how the wire stays in place at the clamp holder if the magnet is not in the area of the circuit:







The picture shows the direction of magnetic field between the poles of the magnet, for the U-shape magnet.

The U-shape magnet is placed in the area of the electric circuit. If the student closes the circuit, the wire starts moving. The direction of the aberrance depends on the direction of the magnetic field.

Following the learning objectives, the students are expected to be able to:

- Compare the effects of the magnetic fields on the charged particle;
- Determine the direction of the Lorentz force on a moving charged particle and on a current-carrying wire, according to the right-hand rule.

References

[1] J. Piaget, “The Psychology of Intelligence”, London: Routledge and Kegan Paul (1951).

[2] Fundación para Estudios Biomédicos Avanzados, Facultad de Medicina - U. de Chile, “Teacher Professional Development in Pre-Secondary School Inquiry-Based Science Education” (IBSE) Editors: Wynne Harlen and Jorge E. Allende (2009).

[3] J. Trna, “How to Educate and Train Science Teachers in IBSE Experimentation”, In: IMSCI 2013. The 7th International Multi-Conference on Society, Cybernetics and Informatics. Proceedings (pp. 176-180). Orlando(USA): International Institute of Informatics and Systemics. ISBN 978-1-936338-83-2., At Orlando, USA, (2013).

[4] Reports on Physics Education in Schools around Europe and the state of the art in 3D Virtual Worlds, Progetto “World-of-Physics: An innovative virtual reality educational environment for school physics education”. Erasmus + - Strategic Partnership. Agreement Number: 2016-1-Cy01-Ka201-017371. http://worldofphysics.etcenter.eu/index.php/en, (2016)

[5] T. Chesney, S.H. Chuah, R. Hoffmann, “Virtual world experimentation: An exploratory study. Journal of Economic Behavior & Organization”, 72, 618-635 (2009).

[6] S. De Freitas, G. Rebolledo-Mendez, F. Liarokapis, G. Magoulas, A. Poulovassilis, “Learning as immersive experiences: Using the four-dimensional framework for designing and evaluating immersive learning experiences in a virtual world. British Journal of Educational Technology, 41, 69-85 (2010).

[7] Z. Palkova, M. Palko, K. Kovas, F. Grivokostopoulou, I. Hatzilygeroudis. “World Of Physics and VR4STEM case studies - How virtual reality attracts the educations”, *ICERI 2017 Proceedings*, pp. 1318-1324, (2017).

[8] T. de Jong, M. C. Linn, Z. C. Zacharia, "Physical and Virtual Laboratories in Science and Engineering Education" Science; Vol. 340, Issue 6130, pp. 305-308, DOI: 10.1126/science.1230579, (2013).

[9] M. Gentile et al. "A Semantic Frame Approach to Support Serious Game Design". In: Bottino R., Jeuring J., Veltkamp R. (eds) Games and Learning Alliance. GALA 2016. Lecture Notes in Computer Science, vol 10056. pp 246-256, Springer, Cham, (2016).

[10] E.Trnova, J. Trna, "Motivational Effectiveness of a Scenario in IBSE", Procedia - Social and Behavioral Sciences, Volume 167, pp. 184-189 (2015).