Lesson 7
Artificial Satellites and the Modern Professions II

Teaching Scenario

MAIN IDEA

According to NASA, more than 2.250 artificial satellites are in orbit around Earth[1]. The signals of these satellites are not only used by a vast array of professionals (scientists, mechanical engineers), but also find numerous applications in everyday life (GPS-telecommunications). Satellite science contributes to the improvement of the quality of our life, and shall continue to further advance science and space exploration.

GENERAL AIM OF THE SCENARIO

The general aim of the teaching scenario is that the students understand the way that satellites function, become acquainted with some of their applications, and discover their contribution in the modern labor market.

SCIENTIFIC CONTENT

Satellites are classified in two categories:

a) natural and

b) artificial

The natural satellites of our solar system are those celestial bodies which orbit around other celestial bodies. For example, the Moon orbits around Earth, therefore it is called the natural satellite of Earth. Mars has 2 natural satellites (Phobos and Deimos), Jupiter has 69 natural satellites (the largest being Ganymede and Callisto), Saturn has 62 natural satellites (the largest being Titan and Rhea), as well as a system of rings which is considered as a group of myriad tiny satellites. Uranus has 27 and Neptune has 14 natural satellites.

Artificial satellites are artificial objects set into orbit around celestial bodies. An artificial satellite set into orbit around Earth, and moving above the equator with

[1] NASA-Goddard Space Flight Center list

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such a speed, so that it appears motionless, is in a geostationary (geosynchronous) orbit. Geostationary satellites are mainly used in telecommunications.

A satellite is set into orbit through the launching of carrier rockets. A carrier rocket may be a multistage rocket. As the launching begins, the fuels of each stage are exhausted, and then each stage is detached gradually and falls away, in order for the rest of the carrier rocket to continue its route with less weight, therefore with even greater velocity. At some moment the rocket reaches the desired height with the appropriate velocity, and the satellite can revolve around Earth. The rocket and the satellite are monitored through specially designed computer systems operated from the control centers on Earth, in order to perform automatically the required corrections so that the satellite may be set into the desired orbit.

The shape of the orbit, in which a satellite is set, depends on:

a) The height of the orbit of the satellite.

b) The velocity of the satellite at the moment it is set into its orbit.

c) The direction of the line segment joining the center of the Earth and the satellite. The orbit can be almost circular in shape; therefore it is called as “circular orbit”.

Artificial satellites, according to the type of their orbit and the height of their orbit, are classified into:

a) Low Earth Orbit (LEO) satellites.

b) Medium Earth Orbit (MEO) satellites.

c) Geosynchronous Orbit (GEO) satellites.

Artificial satellites, according to their use, are classified into:

a) Telecommunication satellites.

b) Meteorological satellites.

c) Military satellites.

d) Navigation satellites.

e) Environmental satellites.

Satellites are very useful for space missions as well, as they can take images and send them for processing to the control centers on Earth. Some satellites operate

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in the infrared that is in a part of the spectrum of the electromagnetic radiation not visible to the human eye.

IDEAS OF THE STUDENTS

- Most of the students have an optical understanding of vision, that is, they understand only the visible part of electromagnetic radiation (Libarkin et al., 2011).
- Many students think that radiation is invisible, and that light is something different (Neumann, 2014).

A) INSTRUCTIONAL OBJECTIVES

Knowledge:

The students, after completing the lesson, will be able to:

- Process simple satellite images from space missions.
- Understand the existence of infrared radiation and its use by satellites.
- Recognize that complex constructions, such as satellites, are based on simple principles.

Skills:

The students, after completing the lesson, will be able to:

- Construct an electric circuit with simple materials.
- Become familiarized with pictures taken from satellites.

Attitudes:

The students, after completing the lesson, will be able to:

- Cooperate in groups.
- Obtain a positive attitude towards science.
- Obtain a positive attitude towards STEM professions.

B) TEACHING TOOLS AND MATERIALS

- Video projector
- PC H/Y
- Internet connection
- Storytelling video
- Experimental arrangement
- Video
- Power point presentation
- Worksheet of the student

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- Evaluation sheet of the student

C) TEACHING METHODOLOGY

We suggest the specific teaching proposal (Inquiry-based learning) based on the following theoretical assumptions:

A. The new knowledge is constructed by the student and is not transmitted by the teacher. The already existing knowledge plays a significant role for the learning of the students. Based on the social dimension of knowledge, learning is conducted through social interaction.

B. The teaching is structured from the specific to the abstract, or from the partial to the general.

C. The use of analogies in teaching connects the already existing knowledge of the student with the new knowledge.

D. The cooperation between the students in small groups facilitates their social interaction and their learning, especially in what concerns difficult cognitive goals.

E. The teaching of aims relevant to science is preferably to be conducted in a direct manner, where each stage of the scientific methodology is presented and evaluated distinctly.

As it has been pointed out (Egger, 2009a, Egger 2009b), the teaching about the scientific procedures can be based on the following ideas:

a. To make the scientific procedures explicit instead of implicit to the students.
b. To use storytelling.
c. To use real data

In the present teaching scenario, the scientific procedures are explicit. In our teaching approach we use simulations and images and also real data. Also, activities of constructivist teaching are included, such as the promotion of the ideas of the students by asserting their own hypotheses, and the meta-cognitive activity of the comparison between the hypotheses and the conclusions of the students. The teaching scenario also includes an activity which aims to connect the object of astronomy, and more general, science and engineering, with the labour market.

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F. The instructional procedure followed is in accordance with the inquiry-based learning method that includes the following steps:

- The phenomena
- Questions by the students
- Questions of the lesson
- Answers/Hypotheses
- Experimentation (data from simulations and images)
- Conclusion
- Comparison between the initial hypotheses and the final conclusions of the students.
- Generalization
- Extension/Application.

Open-Structured Inquiry

The inquiry-based method of learning-teaching may be determined either as a non-structured or open inquiry, or as a structured inquiry. The subject (teacher or student), who determines the procedure and the activities, also determines the type of the inquiry method. According to the open inquiry method the student is the one who determines the phenomena of study, the questions, the procedure, the conclusions. According to the structured inquiry the teacher is the one who determines the majority of the teaching variables, whilst the students participate in the procedure and reach conclusions, which are then used in order to answer the questions (Bunterm et al., 2014).

The proposed method of teaching is a combination of open inquiry and structured inquiry. The activities up to the point of the questions posed by the students are the beginning of an open inquiry procedure, while the rest of the teaching course follows the lines of structured inquiry.

D) CREATION OF THE EVALUATION TEST

The evaluation (knowledge) test has been constructed based on the following principles:

- The questions correspond to the teaching aims.

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- There were used questions of many forms (of objective and open type) (Kassotakis, 2010).
- In the attitude questions the students answer with “yes” or “no”[2].

E) SCENARIO DURATION

Two teaching hours, about 90 minutes.

F) STAGES OF THE TEACHING APPROACH

Introduction-Frame of the lesson (2 minutes)

The students are divided into working groups of 4-5 persons. The worksheet is handed to each group. The aims and the course of the lesson are announced.

Activity 1: Storytelling with video (7 minutes)

The video with the storytelling is presented. The teacher controls the presentation.

<u>Storytelling</u>

Troy has finally fallen! Agamemnon knows that Clytemnestra and all the citizens of Mycenae wait in agony for the news. 550 kilometers separate them. But he wastes no time. The message arrives from Troy to Mycenae in only one night! But it was carried neither by ship nor by messenger.

“Yet who so swift could speed the message here?”
wonders the Chorus in Aeschylus’ tragedy “Agamemnon”

And Clytemnestra answers:

From Ida’s top Hephaestus, lord of fire,

Sent forth his sign; and ever on,

Beacon to beacon sped the courier-flame

....

And Troy is taken, and by this sign my lord

Tells me the tale, and you have learned my word.

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[2] The analysis of the attitude questions can be performed either by the classic Item Response Theory (Türk, 2015) or the modern corresponding theory (Tang, 2016). The teachers can find many more similar questions in the paper of Chapman, Catala, Mauduit, Govender και Louw-Potgieter (2015) “Monitoring and evaluating astronomy outreach programmes”.

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And now you will be wondering: How did this message arrive? It arrived through a network of lit torches, the phryctorias' system! Through a telecommunication network, that the ancient Greeks had devised. Phryctorias, from the word "phryctos", meaning torch, and the word "houros", meaning sentry. And now listen how it worked: They choose the most appropriate hill tops, built small towers. At night with fires and during the day with smoke signals they sent agreed on messages in a very short period of time. Phryctorias!

Later, electricity opened new horizons, but the phryctorias' of the ancient Greeks were the ancestors of the telegraph, the Morse signals, or of SMS messages.

The days, when people used fire to send their messages, they lived close to nature; in complete harmony with it. They knew how to look around them: the lightings, the thunders, the natural phenomena, the phases of the moon, the travels of the Sun. and all these wonders that they saw happening filled them not only with amazement but also with fear. This is why the learned to observe them and to respect them. They consulted the sky when they wanted to travel with their ships. They knew that the appearance of the "Pleiades", meant the coming of spring and the "ploes', the sea travels could begin. They knew that when the "Hyades" appear in the sky, they could begin sewing as this marked the coming of the season of rains. They looked around them and everything, the winds, the lightings, the rainbows, everything… were the consultants of both seamen and farmers.

They said that they could predict the weather for a period of one year. The weather of a whole year. How? By "examining" the first twelve days of the eighth Moon of the year.

They said that animals, their behavior, indicates the weather of the coming days; so, when they saw lambs sitting close to each other, with their heads down, they understood that rain was coming. Or, when the Sun had a halo, or the Moon an aureole, then they understood that the rains were coming.

Many years have passed since then. Nowadays, we have satellites. Satellites for every possible use. Telecommunications satellites, that send messages from the one end of the world to the other in no time. And we can even talk with our beloved ones who are abroad while we see them on screens…

Satellites that predict the weather, that warn us about extreme weather conditions. Satellites that are always by our side and do not let us get lost in our travels thanks to the use of GPS. Spy satellites that are controlled by the army. But, listen to something paradoxical indeed… They say that the US and the Canadian Army apart from their satellites also use trained carrier pigeons. I wonder…why?

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Activity 2: Projection of images (2 minutes)

The teacher projects images related to satellites, in order to induce questions to the students.

Activity 3: Questions of the students (3 minutes)

The students are guided in order to formulate their questions related to the storytelling and the projection of images, and to write them down on the worksheet.

Activity 4: Questions of the lesson-teacher (3 minutes)

1. How are the satellite images used in space missions?
2. How does a satellite work in the infrared, or how do the satellites see at night?
3. Can I construct a device that may detect the infrared?

Activity 5: Answers-hypotheses of the students (5 minutes)

The students, based on their experience, the storytelling, and the images, answer to the questions above on the worksheet, without any aid from the teacher.

Activity 6: How are the satellite images used in space missions? (7 minutes)

The spacecraft Rosetta conducted an extensive study of the Comet 67P/Churyumov-Gerasimenko from May 2014 to September 2016 [3]. Apart from the study at a distance, one space robotic lander, Philae, was launched from Rosetta (Image 1) and landed on the surface of the comet on 12 November 2014. Philae stopped to communicate with the spacecraft on 9 July 2015. On 2 September 2016, just before the end of the mission, Philae was located with the help of a satellite image taken by Rosetta (Image 2).

3 For more: http://sci.esa.int/rosetta/

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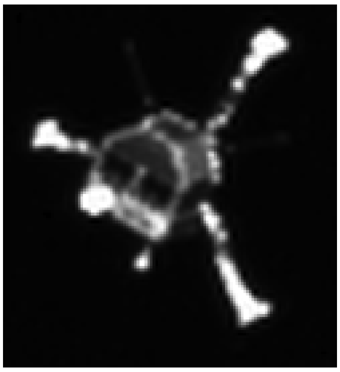

Image 1: Photo of Philae during its release from Rosetta *http://www.esa.int/spaceinimages/Images/2014/11/Lander_departure*

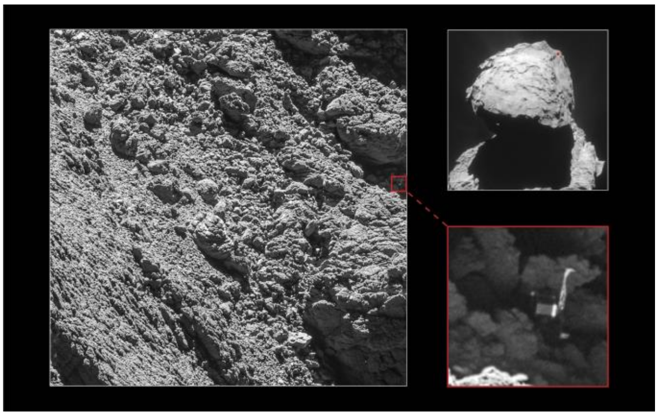

Image 2: The image by Rosetta that located Philae on the surface of the comet 67P/Churyumov-Gerasimenko. http://www.esa.int/spaceinimages/Images/2016/09/Philae_found

In the specific activity, the students are asked to try and locate by themselves the robotic lander Philae by observing the relevant satellite image (Image 2). The teacher projects (a) Image 3, where a part of the surface of the comet is visible, as recorded by Rosetta, and (b) the image of the robotic lander Philae (Image 1), so that the students may understand what they are looking for. The students record their answers on the worksheet.

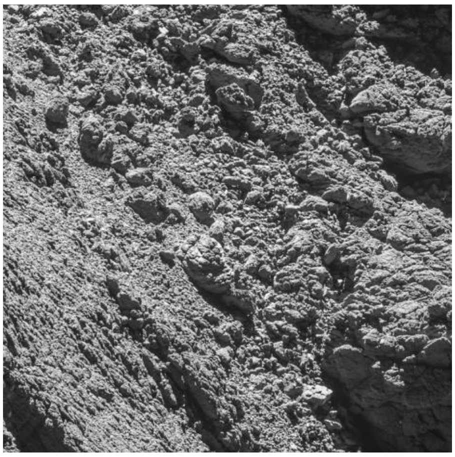

Image 3: Part of the surface of the comet, where the robotic lander Philae is located (http://www.esa.int/spaceinimages/Images/2016/09/Philae_found).

Activity 7: How does a satellite work in the infrared, or how do the satellites see at night?

In the specific activity, the work groups of the students recognize and detect the infrared radiation by using simple materials.

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Materials:

- Remote control of electronic device
- Cell phone with camera

Steps of the activity:

Step 1: The teacher projects the image of the electromagnetic spectrum (Image 4). The students are asked to write down which colors they see.

Step 2: The students are asked to recognize from Image 4 where the infrared spectrum is located, as well as to report in which everyday activities it is encountered.

Step 3: The students activate the camera of a cell phone and aim with the remote control by pressing the buttons (Image 5). They write down their observations on the worksheet. The teacher comments that the satellites, when they detect the infrared, work in exactly the same way[4].

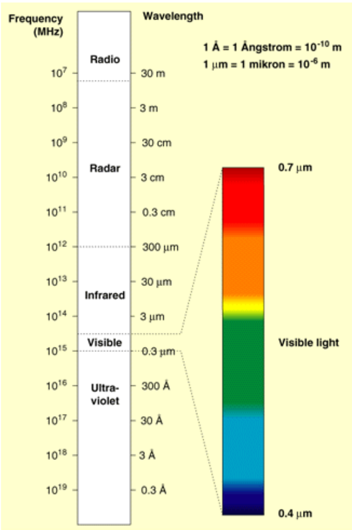

Image4: The electromagnetic spectrum (http://www.esa.int/images/02-spektrum.gif)

Image 5: Detection of the invisible infrared radiation by the camera of a cell phone

[4] An interesting question that arises is that although we cannot see with naked eye the infrared radiation, we can see it with the camera of a cell phone. We note that the detection is possible with a digital camera. The answer is that the sensors of the camera do not obey the same limitations the human eye follows. Specifically, the camera cannot detect light of a wave-lenght of more than 1100 nm, while the corresponding limit of the human eye is the 720 nm. The usual remote controls emit at 850 nm, therefore they are detected by the cameras, but not by our eyes. One other question is why the infrared appears in color on the screen of the camera. The answer lies in the technical details of the construction of the screen, that depicts any received light as a combination of the colors red-green-blue (RGB).

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Activity 8: Can I construct a device that detects the infrared? (25 minutes)

In the specific activity, the students are asked to detect the infrared radiation by constructing a simple electric circuit for photo-detection. In reality, they model circuits existing in the sensors of the artificial satellites in orbit around the Earth.

Materials:

- Board for immediate assembling and disassembling electric circuits
- Resistor of 62 Ohm
- LED lamp
- Phototransistor of 850 nm
- Connection cables
- Voltage source of steady current, of 3 to 9V (batteries or power supply)
- Remote control of electronic device

Steps of the construction:

Step 1: The diagram of the photo-detecting circuit is handed out (Image 6), and the students are asked to construct, with the help of the teacher, the circuit with the materials given to them[5].

Step 2: After completing the construction, the students are asked to try and detect the infrared radiation emitted by a remote control: They point with the remote control the phototransistor and observe the LED lamp.

Step 3 : The students write down their hypotheses about the function of the circuit on their worksheet. Then, they present their views in the classroom.

[5] For the connections on the board: The columns inside the board, in the region defined by the letters ABCDE and FGHIJ are vertically short-circuited, which means that the 5 holes of each column have the same current. The rows on the upper and lower part of the board are horizontally short-circuited, which means that the 60 horizontal holes have the same current. Here we connect the source. Some boards have at their middle an empty space. In these boards, the horizontal holes are short-circuited in two groups: from 0 to 30 and from 31 to 60.

The long leg of the LED lamp and of the phototransistor corresponds to +.

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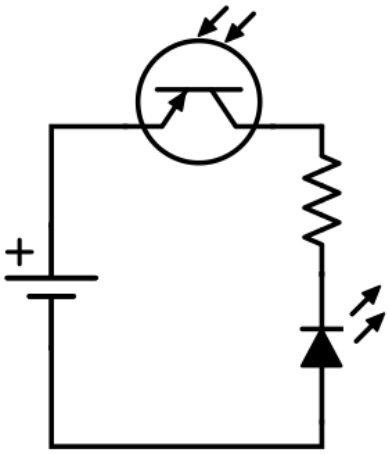

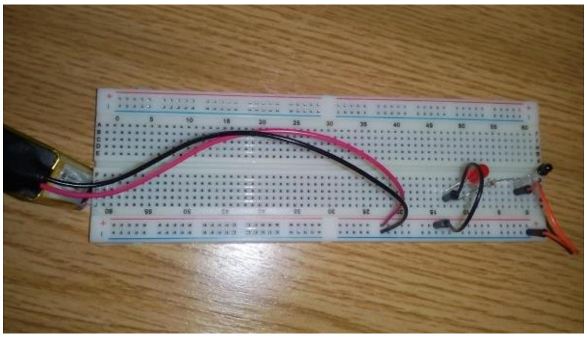

Image 6: The light-detecting circuit. Diagram and photo

Activity 9: Comparison between the final conclusions and the initial answers of the students (5 minutes)

The students, in their working groups, compare their initial answers with the conclusions.

Activity 10: Extension-Application of the conclusions (2 minutes)

The students answer to questions about the application of the conclusions.

Activity 11: Connection of the lesson with vocational training (10 minutes)

In the specific activity, the students are asked to propose a solution to a problem related to the STEM specialties[6]. Each group presents its proposals to the rest of the classroom.

Activity 12: Evaluation sheet (5 minutes)

The evaluation sheet is distributed for being filled out by the students.

[6] STEM specialties: Astronomer, astrophysicist, physicist, electric engineer, aeronautical engineer, mechanics engineer, telecommunications engineer, computer engineer, technologist, meteorologist, geologist, mathematician, technician, chemist, biologist.

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