Lesson 8

Astronomy and the Scientific Method I – Gravity

Teaching Scenario

GENERAL AIM OF THE TEACHING SCENARIO

Astronomy has contributed fundamentally to the comprehensibility of the Cosmos, to the progress of science and to the development of the scientific method.
The students, through various presentations and examples from the history of astronomy, learn about the comprehensibility of Cosmos through scientific laws and scientific methodology. Particularly, the students learn the stages of scientific procedures in order to comprehend how generalizations and scientific laws are formulated.

Scientific Content
Gravity is the property of the mutual and simultaneous attraction between bodies that posses mass.

The moon completes a revolution around its axis in 27 days, 7 hours and 23 minutes, namely the same time that it needs to complete one complete revolution around Earth.

IDEAS OF THE STUDENTS

- Only one scientific method, which always includes an experiment, exists.
- All scientists perform experiments.

A) INSTRUCTIONAL OBJECTIVES

Knowledge:

- The students may report or recognize the different stages of scientific procedures.
- The students understand that one scientific discovery may not necessarily involve an experiment.

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Skills:

The students upon the completion of the lesson will be able to:

- Derive conclusions (generalizations, laws) from different types of data.
- Apply the conclusions for developing scientific rationales, and explain or predict physical phenomena.
- Use the simulation "Orbits and Gravity"
- Apply the inquiry- based learning method

Attitudes:

- The students are in a position to cooperate in groups
- The students develop a positive attitude towards science
- The students develop a positive attitude towards STEM related professions

B) TEACHING MEANS AND MATERIALS

- Images, simulation ("Gravity and orbits", PHET), Presentation, Work Sheet
- Video Projector
- PC
- Presentation
- Presentation with presentation software
- PC Simulation
- Worksheet of the students
- Evaluation sheet for the student

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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.

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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. 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.

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

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- 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.

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D) CREATION OF THE EVALUATION TEST

The evaluation test was developed according to the following principles:

- The questions correspond to the teaching aims.
- There were used questions of many forms (of objective and open type), which correspond to the teaching aims (Kassotakis, 2010).
- The students answer to the attitude questions with a “yes” or “no”[1].

E) SCENARIO DURATION

Two teaching hours (90 minutes).

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

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F) STAGES OF THE TEACHING APPROACH

Introduction – Frame of the Lesson (2 minutes)

The aims and the course of the lesson are introduced. The central teaching aim is the investigation through astronomy of scientific procedures. The course of the lesson follows the inquiry-based learning methodology. The quote of Einstein is presented: "It is a miracle that Cosmos is comprehensible."

Activity 1: Phenomena (12 minutes)

Presentation with the quote of Einstein, and images from Science, Technology and Mathematics, in order to induce questions from the students.
The students form working groups of 4-5 people. The worksheet is distributed to each group. The video with the storytelling is presented. The teacher handles the presentation with the images, elaborating whenever necessary.

STORYTELLING

Humans counted the passing of time with the succession of day and night, with the succession of the seasons, with the motion of the celestial bodies. So, they developed calendars that followed the Sun and the Moon during the whole year, in order to arrange the movements of their flocks, the sowing of their grains. Humans always traveled the seas, always plowed and sowed the ground. But, they knew, that all this had to be done at the right moment, the right time. For this reason, time was deified in their minds, and they explained everything they could not explain otherwise, with Saturn, whom he considered to be the regulator of life and death, of the rebirth of nature and humans. They looked at the sky, and he, always with his eternal wisdom, showed them signs. Therefore, when humans saw the Hyades shining in the celestial canopy, he understood that autumn, with its beneficial rains was coming. But, when the Pleiades were moving slowly across the sky, then he understood that this was the right time for the "ploes", the travels. Humans looked always at the sky, and liked to watching the stars. They watched them rising and setting always in the same order, the same regularity; the only difference being, that these creatures lived in the sky, just as they were living on Earth. But immortal creatures, since they were always there. They liked to connect the stars with imaginary lines and create forms of heroes and gods. They made stories about them. So, when they saw three stars in a row always running behind a cluster of seven stars, they said, it cannot be, these three stars must be the belt

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of a glorious hunter, Orion,
who runs to catch Pleione, his beloved one. As the years were passing, the mythological representation of the world and of the motion of the planets is abandoned, with the dawning of philosophical inquiry. The laws for the motion of the Sun and the Moon, of the planets, that were postulated with satisfactory accuracy by the philosophers of the ancient world, place the foundations of scientific thought. As in our days, where we make telescopes, space-crafts, so in those days they constructed scientific instruments for the study of the sky. Twenty-two centuries ago, the Antikythera Mechanism is constructed, an instrument that summarized the whole of the scientific astronomical thought of that era. It could determine the places of the Sun, the phases of the Moon, it could predict the time of the eclipses and of the Olympic games. The Universe as it was conceived then was depicted on its front; with the planets, the Sun, the Moon, in their complex dance on the celestial canopy. But, as Aristotle said, the desire to study, to observe, to learn, is in the nature of man

This is why our exploration of the celestial canopy, our effort to solve all the mysteries and the enigmas it hides, continue perpetually. But, which is this primordial force that drives us to discover all these mysteries, to solve all these enigmas?

It is perhaps, as the astrophysicists say, “because we are truly made out of stardust” ?

Activity 2: Questions of the students (2 minutes)
The students are guided in order to formulate their questions about the presentation and then write them down on the worksheet.

Activity 3: Questions of the lesson (2 minutes)
The following questions are posed by the teacher:

1. Which scientific procedures do scientists follow?
2. Which is the nature of the work of scientists?

Activity 4: Answers/Assumptions of the students (5 minutes)
The students answer based on their experience and the presentation to the above question in their Worksheet.

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Activity 5: Testing the Assumptions-Answers- Formulation of the Law – Application of the Law (25 minutes)
The students are guided on the basis of the storytelling and the presentation (images, simulations) in order to conclude the scientific procedures and the whole course of the scientific method. **At the same time, Activity number 6 is gradually filled in on the Worksheet** (steps of the scientific method**).** The simulation is handled by the teacher. Based on the simulation the following questions are investigated:

a) Which is the revolution time of the Earth around the Sun?
b) Which is the revolution time of the Moon around the Earth?
c) Which is the relation between the gravitational interaction and the distance between the planets?
d) Which is the relation between the gravitational interaction and the masses of the planets?

The derived conclusions are of a qualitative nature; the mathematical relation is simply presented to the students.
The conclusions are generalized for all bodies of mass.
The law of gravitational interaction is applied by the students in order to explain/predict the phenomena.

Activity 6: Conclusions about the scientific method (5 minutes)
The students conclude that some of the scientific procedures are: the observation of the phenomena, the formulation of questions from experience or simulations, the derivation of conclusions, the formulation of generalizations-scientific laws, the application of generalizations. They also learn, that a scientific discovery may be concluded from a simulation.

Activity 7: Comparisons between the initial answers of the students with the final conclusions (5 minutes)
The students in their groups, compare their initial answers with their final conclusions to question 3 about the work of scientists.

Activity 8: Application/Extension (20 minutes)
The students, based on the simulation *gravity and orbits* (https://phet.colorado.edu/sims/html/gravity-and-orbits/latest/gravity-and-orbits_en.html), apply the inquiry-based learning method to a phenomenon of their choice, by filling in the following table: (the last three fields may be given as homework)

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Phenomenon:

Questions:

Assumptions:

Testing of the assumptions:

Conclusions:

Application/Generalization:

(For example: For the motion of the Earth around the Sun, the question is: Which would be the motion of Earth, if the gravitational force did not exist?)

Presentation of the work of the students

The students present their work in front of the classroom

Activity 9: Evaluation Sheet (6 minutes)

The evaluation sheet is distributed and filled in by the students.

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