SPACE awareness

SOLAR SYSTEM

DIDACTIC COURSE FOR SECONDARY LEVEL

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Information about the course

Curriculum topic:
The Solar System

Category:
Our Wonderful Universe

Keywords:
Solar System, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune

Age range:
12–14 and 14–16 years

Education level:
Primary

Language:
English

Students' prior knowledge:
- The names of the planets

- Ability to use proportions and scales

Didactical hours:
13 didactical hours

Orientation-Conceptualisation: 1 didactical hour

Investigation: 6 did. hours

Conclusion: 1 did. hour

Discussion: 5 did. hours

BRIEF DESCRIPTION

The Solar System has always been a very interesting subject for all age groups. In this activity, students will construct a scale model of the Solar System and enrich their knowledge on the subject.

EDUCATIONAL OBJECTIVES

- Cognitive Objectives (Types of Knowledge): Factual, Meta-cognitive
- Cognitive Objectives (Processes): To think critically and creatively
- Affective Objectives: To respond and participate
- Psychomotor Objectives: To perform independently, skilfully, and precisely

STEPS

ORIENTATION

Present the following video to your students.

https://www.youtube.com/watch?v=Usj6viU0AaI (Length, 3:09 minutes)

During the video, ask your students the following questions to initiate a discussion.

"Is Earth part of a bigger system?"

"Is our Solar System part of an even bigger system?"

Give the students ample time to answer. Give all the students the opportunity to speak their mind. Discuss the Milky Way and the position of our Solar System in it. Then direct the conversation towards the exploration of the Solar System.

"How do scientists explore the Solar System?"

You can start by discussing early observations of the Solar System made with the eyes (until 1609). In this part, you can use Stellarium to view the night sky. You may also talk about telescopic observations, how early observers used drawings before the invention of photography, and telescopic photos and data from space missions (like Voyager I and II).

Finally, present the goal of the activity to your students.

"In this activity, we are going to explore our Solar System. Our goal is to learn some basic information about the objects that are part of our Solar System and to gain a better understanding of the size of our Solar System as well as of Earth compared to other planets and the Sun."

EXTRA GUIDELINES

Suggested ICT tools

- http://stellarium.org/
- You may also use some phone apps: https://play.google.com/store/search?q=solar%20system&c=apps&hl=el/

Tips for a diverse classroom

- Invite all students to contribute to the discussion even if they don't know the right answer. Ask them what points they found confusing.
- Invite the students to speak. The sense that they are welcome to speak without being put on the spot can be a strong inducement to participate.
- Give students time to answer and be sure to pay as much attention to the hesitant ones as to others.

Main skills involved

- Active listening – Paying full complete attention to the teacher while he/she presents the problem statements and aphorisms and to other students' ideas about how to solve the problems.
- Speaking – Speaking their minds on each problem/aphorism and pointing out key points of the problem that may lead to a solution.

CONCEPTUALISATION

Question

Conceptualisation is about helping students understand the concepts and objects involved in the activity (models, scales, stars, planets, satellites, asteroids-meteors, comets, and nanoplanets).

"Let's see what we already know about the Solar System.

What are the components of the Solar System?

What is the difference between a star and a planet?

What is the difference between planets and asteroids?"

Encourage students to ask similar questions about the Solar System. For example

- How many stars are there in our Solar System?
- Which is the biggest planet?
- How far are the planets from the Sun?
- Do all planets have moons?
- Can a moon be bigger than its orbiting planet?
- How many tails does a comet have and why?
- Is it possible that Mars will appear as large as a full moon in Earth's sky?

During the conversation, make sure you keep a list of the objects students mention on the board. Alternatively, you can use a Padlet to keep your list online.

After concluding with the different types of objects found in our Solar System, it is time to talk about their sizes.

How much bigger or smaller is the Sun compared to Earth?
How much bigger or smaller is the Moon compared to Earth?
How can we understand the relative sizes and distances between the planets?

Hypothesis

One of the main objectives of the activity is to help students understand the scale of our Solar System. To this end, ask your students to form a hypothesis about the relative sizes of different objects in our Solar System. Ask them to create a mock-up of our Solar System using the objects from the list compiled in the previous phase. Students can make their mock-up with pen and paper or they can use an online tool drawing tool or Paint. You can share their mock-ups in Padlet in the latter case. If the objects in the list are too many, stick to the most popular ones.

"How big do you think our Solar System is?

Can you create a mock-up to show the relative sizes of the different objects of our Solar System?"

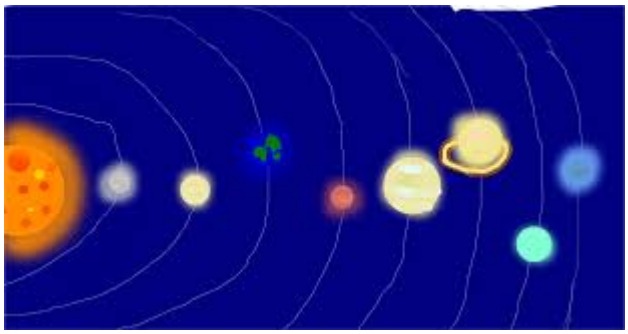

Figure 1. An example drawing from "Sketchport" (not in scale!)

You can conclude this part of the activity by giving your students a little challenge.

"In the next part of our activity, we are going to test your hypotheses about the sizes of the planets and the Sun. But before we do that, let's play a little game.

If you hold out your arm and look at your thumb, you will see that the moon is approximately the same size as your thumb. Now, if I also told you that the Moon is approximately 385,000 km away, can you calculate the diameter of the lunar disk?"

Keep in mind that what we are looking for here is to show students how to make rough calculations easily. This way, they will be inspired and devise intuitive ways to make

calculations even in their everyday life. Therefore, do not focus on accuracy; what we need is a rough estimation of the size.

EXTRA GUIDELINES

Suggested ICT tools

- Online drawing tools: http://drawisland.com/ and https://www.sketchport.com/draw/
- Padlet: http://padlet.com/ (this tool is an online blackboard to write down the objects the students suggest). You can also use a projector and type the ideas the students mention or show their drawings.
- More information about measuring angles and sizes with our body as a ruler: http://www.vendian.org/mncharity/dir3/bodyruler_angle/

Tips for a diverse classroom

- Encourage everyone to express views and concerns.
- If you wish to check if some concepts are clear to some students, direct your question to the entire class, not just to those whom you think the question applies to.
- Including the idea of an alien helping out the astronaut and the two of them becoming friends could be a nice way of showing how people from different cultures can be friends and collaborate.
- See a nice example here: http://www.galileo-mobile.org/galileomobile-expeditions/galileomobile-brabo2014/galileomobile-documentary-brabo2014/ (from point 1.19.00 and on)

Main skills involved

- Critical thinking - Using logic and reasoning to identify the concepts involved, provide preliminary explanations and hypotheses, and map approaches to problems.
- Use of science – Referring to previous knowledge and scientific rules related to the subject.
- Systems evaluation - Identifying variables involved in the problem and the relationships between them so as to make a rational hypothesis.

INVESTIGATION

Exploration

Start this part with the challenge you gave your students. Ask them to present their answers and the rationale behind their answer. The key here is to check if they thought about using triangles and proportions to make the calculation. Conclude this part by making sure that everyone has understood the solution of the challenge. Then initiate a discussion to help your students use this idea and explore the possibility of measuring the size of other celestial objects.

"How can we measure the size of our planet or that of other planets, the Moon, or the Sun?

How did the ancient Greeks know the size of Earth or even that it was not flat?"

Give your students some time to brainstorm. Then show them one (or any) of the following videos:

- https://www.youtube.com/watch?v=F8UFGu2M2gM (From 1.25 to 4.05 minutes)
- https://www.youtube.com/watch?v=G8cbIWMv0rI (Length, 6:41 minutes)
- https://www.youtube.com/watch?v=rIF6Vj6pVNg (Length, 7:28 minutes)

The idea behind these videos is to inspire students by demonstrating how we can make great discoveries with simple observations. After viewing the video(s), show your students how the ancient Greeks were able to measure the size of the Moon and Sun as well as their distances from Earth. You can use the *Measuring_the _solar_system* presentation for this.

"So let's say we want to build a model of our Solar System in an accurate scale. How do you propose we do that?

What information do we need in order to build our model?

How big would you like our model to be?

What other information do we need to gather in order to make our model?"

The idea here is to guide the students to use proportions based on the actual sizes of the planets.

Real size of the object/real distance of the object from the Sun = Scaled size of the object/scaled size of the object from the Sun

In order to build their model, the students will need the diameters of each planet as well as their distances from the Sun. Then they will have to decide how big they want their model to be. In other words, they'll have to decide on the scale of the model. The scale of the model is very important for the overall presentation of the model. If, for example, the students want to use the schoolyard to make the model, they must make sure that the entire model will fit in the yard. Thus, while discussing the scale of the model, students also need to decide how they imagine the final presentation to be.

Some ideas on the presentation

Students can make a model that fits into their classroom or their school.
In case there is the option of making this project in the framework of a bigger social event that includes the citizens of your town, you can build a model that will be spread

across the town itself. If this is not an option, you can make a model based on your town using Google Earth (https://www.google.com/earth/).

Keep track of the ideas and information coming from the students in Padlet. After the students have concluded on the data they need and the scale of their model, encourage them to write down the overall procedure (investigation plan) they plan to follow. This can be a homework activity. Students can write their plan in Padlet or in Google Docs.

Experimentation

Once the students have finished their investigation plan, it is time to start building the model. Encourage your students to decide how they want to work. Divide the class into as many groups as the components of your model.

Each group will have to

- Calculate the proper size of their object and make a model for it
- Find the objects' distance from the Sun
- Collect interesting information about the object and compose a presentation based on this information.

For the construction and painting of the spheres, you can collaborate with the school's art teacher.

Use the *Investigation_sheet_Teacher* document for more detailed information.

EXTRA GUIDELINES

Suggested ICT tools

- http://www.exo.net/~pauld/exnet/spacescience/A%20Handy%20Measuring%20Tool.pdf
- https://www.khanacademy.org/partner-content/nasa/measuringuniverse
- http://nineplanets.org/
- http://stellarium.org/; you can use Stellarium to simulate the night sky in your class.
- http://sciencenetlinks.com/interactives/messenger/psc/PlanetSize.html
- http://www.solarsystemscope.com/
- Investigation organisation
    - https://wiggio.com/#tpl=home_0/
    - https://www.dropbox.com/home/
    - Google Docs
- Tools for the presentations
    - https://prezi.com/
    - http://www.toondoo.com/
    - https://www.powtoon.com/

- Suggested books
    - A Short History of Nearly Everything by Bill Bryson (especially the illustrated edition), chapter 2
    - The Planets by Dava Sober

Tips for a diverse classroom

- Develop a positive atmosphere in the classroom that promotes excellence. Encourage your students (as a group or individually) to consult you if they have problems during their inquiry. This is also an indirect way to get to know your students and thus tackle assumptions you might have about their learning behaviours and capacities based on their gender or cultural background.
- Have high expectations from all your students. Keep an eye on teams and make sure you spot cases in which a student underperforms.
- Encourage the formation of heterogeneous groups across certain characteristics such as gender, race, and level of achievement. You may choose to assign students randomly or ask them to form their own groups.
- Pay attention to the length of time students remain in a group, particularly if the group is not working well.
- Make sure the same students do not always put themselves in the position of leadership. Assigning roles (deliberately or randomly) may assist in ensuring that all students get a chance to take on different responsibilities (manipulating equipment, recording results, reporting back, etc.).
- Take care to reduce cases in which a student may feel isolated. Working in pairs can be a solution in such cases.
- Make sure that you give girls as well as boys opportunities to take leadership.
- Assign all roles to girls as much as you do to boys.
- Create a cooperative instead of a competitive environment within each group and among groups.

Related careers

While doing their research, students can get a very brief idea of how scientists search for existing knowledge on a subject.

To further inspire the students and relate their research to the work of an astronomer, you can print out the tags in the *Students_Tags* file and hand them out to them based on the planet they choose. They can use these tags throughout the activity.

Main skills involved

- Complex problem solving – Understanding the research questions.
- Critical thinking – Using logic and reasoning to understand the investigation plan and its implementation. Proposing modifications if needed and assessing the validity of data received and of the final results of data interpretation.

- Judgment and decision making – Considering possible pathways for recognising errors in the experimentation and data manipulation process. Assessing teammates' proposals and opinions.
- Active listening – Paying full attention to the opinions of teammates.
- Reading and comprehension – Understanding instructions and the relevant theory.
- Monitoring – Assessing self-performance and team performance and taking corrective actions if needed.
- Active learning – Understanding the implementation process and its relation to the problem at hand. Relating information derived from experimentation and data interpretation to knowledge acquired previously and to the problem at hand.
- Time management – Managing experimentation time and not letting the team spend more time than foreseen on the task at hand.
- Systems analysis – Understanding the experimental set-up and how each variable affects the experiment. Manipulating and interpreting the data received. Identifying sources of error and proposing refinements in order to overcome them.
- Coordination – Cooperation within teams, ensuring harmonious and balanced collaboration.
- Social perceptiveness – Being aware of teammates' reactions and understanding why they react as they do.
- Use of science – Using scientific rules and methods effectively to perform experimentation and data interpretation.
- Systems evaluation – Assessing the experimentation process and understanding whether the experiment has been carried out correctly or not. Being able to take the actions needed to improve or correct performance.
- Use of mathematics – Using mathematics to manipulate data and produce final results.
- Quality control analysis – Assessing the results derived as well as the quality of the gathered data. Being able to estimate the sources of error in the experiment.

CONCLUSION

The conclusion phase is where the students do a peer review of each other's work so they can decide as a class what they are going to present. Each team will present its work to the rest of the class in order to decide what the most significant information about each planet is and how it is going to be presented. Suggestions from students need to be considered, and each team may have to make some refinements based on the comments they receive. To guide the students, focus on helping them use the proper scientific words.

"Did you know that scientists have to go through a review board before presenting their work in a scientific paper? The review board decides if their work is publishable and if so, whether there are any changes that need to be made before publication.

Similarly, we are going to review the work of each team so we can decide as a team on the final presentation of our project. Each team will present its work to the rest of the class and note down any suggestions. After that, the teams will make the changes they see fit based on the comments received and finalise their presentation."

Before wrapping up the conclusion phase, ask your students to look back at the mock-ups they created during the hypothesis phase.

"Have a look back at the mock-ups we made at the beginning of the project. Do they match the model you built? If not, what was it that led you to a false perception of the scales of the planets?"

EXTRA GUIDELINES

Suggested ICT tools

Tools that could be useful in the conclusion phase are as follows:

- Research tools (Wikipedia)
- Online collaboration documents for sharing inputs and ideas (Google Docs)
- Shared space (Dropbox)
- Virtual classroom walls (Padlet, Popplet) (for reflecting on the conceptualisation phase)
- Study cards (Studyblue) (for reflecting on the conceptualisation phase)

Tips for a diverse classroom and ensuring gender balance

- Encourage students to include multiple perspectives and consider alternative explanations.
- Don't allow students to be interrupted or intimidated.
- Encourage hesitant students to speak their mind and show them you are especially interested in what they have to say.
- Give students time to draw their conclusions and be sure that you are paying attention to all of them equally.
- Refer to a silent student's work in an affirming way.
- Credit a quiet student by making her or him the expert for a task.
- Ask all students to take turns in presenting conclusions.

Main skills involved

- Critical thinking – Assessing the results derived in order to draw the correct conclusion. Considering alternative explanations.

- Active listening – Paying attention to the opinions of classmates and taking into account their proposals.
- Reading and comprehension – Referring to the literature and relevant theory in order to draw conclusions.
- Speaking – Communicating conclusions to teammates based on thoughts and solid arguments.
- Monitoring – Assessing other teammates' arguments and their degree of contribution to the team. Encouraging quiet teammates to participate more.
- Active learning – Paying attention to classmates and combining opinions to draw correct conclusions.
- Writing – Being able to produce a written report of the experimentation process and how the team came to its conclusions based on scientific knowledge and rational arguments.
- Systems analysis – Being able to comment on the overall quality of the experiment and deciding on whether it was successful or not based on the conclusions drawn.
- Social perceptiveness – Being aware of teammates' reactions and understanding why they react as they do. Understanding if all teammates agree with the team's conclusions and if not, then why.
- Use of science – Using scientific rules and prior and new knowledge in order to draw conclusions based on the data gathered and rational arguments.
- Systems evaluation – Being able to draw conclusions on the overall experimental process.

DISCUSSION

Communication

In this part of the activity, the class gets to present what they have done.

Make sure that none of the presentations ramble and that they stick to the point. Time management is an important skill for this part of the exercise. Set limits for the presentation of each team and help your students keep within these limits.

Encourage the students to advertise their work beforehand. In addition, you can advise them to take pictures during the presentation and collect feedback from the audience. For example, they can ask the audience what they think of the presentation. Did the audience learn new things?

Reflection

Encourage your students to reflect on the experience of the presentation and communicate the feedback they got. They can share the pictures they took as well as the comments from the audience.

"Do you think your model was successful? Did the visitors learn about the essentials of the planets in our Solar System? Did they enjoy the presentation?

If you could change something about your work, what would it be?"

EXTRA GUIDELINES

Suggested ICT tools

- Word clouds (Wordle)
- Photo-sharing and editing tools (Picasa, Instagram, Snapchat, Flickr, Photobucket)
- Padlet
  http://sydor.weebly.com/planet-and-sun-sizes.html/

Tips for a diverse classroom and ensuring gender balance

- Allow the presentation of multiple opinions and perspectives.
- Use examples from multiple backgrounds and perspectives. The same groups should not be always used for demonstrating positive or negative examples.
- Be sensitive to cultural differences in writing styles, recognising that many standards apply to the evaluation of good writing and presenting.
- Be explicit about what is expected and show examples of good writing done by other students.
- Not all students from a particular group share the same views. Respect the different opinions of students.
- A writing exercise may allow all students to express their thoughts on the discussion topic.
- Be sensitive to the experiences of visibly underrepresented students in your class.

Main skills involved

- Active listening – Paying full attention to classmates and to what other teams are presenting. Taking the time to understand what other teams did. Asking questions on their work and results.
- Reading and comprehension – Being able to understand the written reports of other teams and assess them. Being able to read the relevant theory and reflect on new knowledge.
- Speaking – Being able to communicate the work of the team as well as the results derived using proper scientific terms and scientifically valid arguments.
- Active learning – Paying full attention to classmates and taking the time to understand their point of view and compare different points of view.
- Time management – Being able to prepare the model in time and ensuring the presentation fits in the timeframe allowed.

- Social perceptiveness - Being aware of teammates' reactions and understanding why they react as they do while making the final play. Being aware of others teams' reactions during the play and understanding why they react as they do.

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