FIREBALLS AND THEIR IMPACT ON OUR PLANET

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Students will investigate the effects that a fire ball con have impacting on the surface of our planet. Students will conduct two experiments dropping rocks of different size at different heights. They will use mathematics analyses such as making measurements and plotting graphics to find what type of relationship exists between the crater size and the impactor mass and speed.

EDUCATIONAL CONTEXT

AGE

12-13

DURATION

2h

PREREQUISITES

- Origins and structure of our Solar System.
- Kinetics and potential energy.
- Draw lines and points in the coordinate plane.
- Use variables to represent two quantities in a real-world problem that change in relationship to one another. Analyze the relationship between the dependent and independent variables using graphs and tables.
- Recognize and represent proportional relationships between quantities.

EDUCATIONAL OBJECTIVES

WHAT DO YOU AIM FOR YOUR STUDENTS TO LEARN THROUGH THIS ACTIVITY

COGNITIVE OBJECTIVES

Learners' ability to process information in a meaningful way.

- Use measuring instruments and choose appropriate units of measurement.
- Retrieve information from graphs and tables.
- Display data in tables or graphs; create equations or diagrams that model problem situations.
- Provide mathematical arguments to support a strategy or solution.
- Provide or identify an explanation for an observation or a natural phenomenon using a science concept or principle.

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AFFECTIVE OBJECTIVES

Learners' attitudes and feelings that are a result of the learning process.

- Students 'active participation.
- Willingness to respond or satisfaction in responding.
- Willingness to receive or attend to phenomena or stimuli.
- Showing the attitude to solve mathematical problems by self.
- While solving mathematical problems maintaining patience till reaching the answer.

PSYCHOMOTOR OBJECTIVES

Learners' ability to use motor skills to learn.

- Listening to the teacher's stimuli and instructions carefully.
- Taking measurements with precision and accuracy.
- Drawing graphics and tables with accuracy.

CONNECTION TO THE CURRICULA

- Write learning subjects and chapters of your country's curricula where your activity could be implemented.

- Mathematics: numeri, spazio e figure, dati e previsioni.
- Science: Fisica, Astronomia e Scienze della Terra.
- Key Competences for Lifelong Learning in the European Schools: mathematical competence and competence in science. Personal, social and learning to learn competence.

EDUCATIONAL APPROACH

Inquiry based learning

In the following pages there is a template based on the inquiry learning method. It is not necessary to follow this method. You can choose any approach you like.

ORIENTING & ASKING QUESTIONS

STEP-BY-STEP WORKING SHEET (Doc.1)

Orienting: Provide Contact with the content and/or provoke curiosity

- Show the class the photo of the crater on the rocky planets and satellites of our Solar System: Mercury, Venus, Mars, Moon, Ganimede, Callisto.
  https://www.nasa.gov/image-article/happy-little-crater-mercury/
  https://science.nasa.gov/resource/dickinson-crater-on-venus/
  https://www.nasa.gov/image-article/spectacular-new-martian-impact-crater/
  https://www.nasa.gov/stem-content/impact-craters/
  https://www.nasa.gov/image-article/striking-crater-jupiters-moon-ganymede/
  https://photojournal.jpl.nasa.gov/catalog/PIA01657

- Show the class the photo of the craters on the Earth (e.g. Meteor Crater in Arizona).
  https://barringercrater.com/blog/interactive-earth-impact-database

https://eu.azcentral.com/story/travel/arizona/road-trips/2017/10/17/meteor-crater-arizona/541387001/

- Show the class a brief animation of the formation of an impact crater.
  https://www.astronomynotes.com/solarsys/s8b.htm

- Show the class video and journal articles of the most famous fireballs impacting on Earth and their consequences (e.g. 1992 Peekskill Meteor landing on a car, Tunguska event occurred in Russia in 1908, Chicxulub crater under the Yucatan Peninsula in Mexico, Chelyabinsk - 15th February 2013)
  https://eu.lohud.com/videos/news/local/westchester/peekskill/2017/10/05/video-peekskill-meteorite-25-years-later/106295236/
  https://www.youtube.com/watch?v=F7PX51IeMbU
  https://www.youtube.com/watch?v=dNRTtLLuNM8
  https://www.youtube.com/watch?v=n1TL_jaVijY

- Showing the class journal articles and video about Perseids meteor shower.
  https://science.nasa.gov/solar-system/meteors-meteorites/perseids/
  https://www.theguardian.com/science/video/2013/aug/13/perseids-meteor-shower-timelapse-video

Define Goals and/or questions from current knowledge

- Discuss about meteoroid, meteor and meteorite with the class, asking whether they have ever seen a fireball and if falling stars can have origins from comets and asteroids.
- Discuss with the class about the reasons these bodies impact on Earth and other planets.
- Discuss with the class about the reasons the Moon has much more craters than the Earth, asking about their atmosphere, erosional events, tectonic processes and volcanism.
- Discuss with the class about the factors might affect the size of the crater and what effect they might have.

HYPOTHESIS GENERATION AND DESIGN

Generation of Hypotheses or Preliminary Explanations

- 1) If the mass of the meteor increase it grows the crater dimension.
- 2) The circular shape of the impact crater does not depend on the meteor shape.
- 3) If the velocity of the meteor increase it grows the crater dimension.

Design/Model

In order to test hypotheses 1-2 and 3, the class will perform two different experiments using the following materials to simulate the Earth's surface and the meteors.
A container filled with wet sand or wet coffee grounds (10 cm thick), to simulate the Earth's surface.
Six different bullets (small stones, glass or iron spheres) to simulate meteors.
A tape rule positioned vertically to the side of the container to set a fall rate.

PLANNING AND INVESTIGATION (Doc. 2 - 3)

In order to test hypotheses 1-2 the class will perform **Experiment1** following these steps.
1) Measure the mass of each of the six bullets and write it down on a table below the variable X.
2) Drop each bullet from the same height of 30 cm.
3) Measure the diameter of the crater and write it down on the table below the variable Y.
4) Note if the crater has a circular shape and note down on the table.
5) After dropping the bullet and making measurement, smooth the sand.

In order to test hypothesis 3 the class will perform **Experiment2** following these steps.

1) Choose the lightest bullet and drop it from an eight of 10 cm and write this value down on the table below the variable X.
2) Measure the diameter of the crater and write it down on the table below the variable Y.
3) Increase the drop height (increasing in 10 cm increments up to 1 m, but this can be changed)
4) After dropping the bullet and making measurement, smooth the sand.

ANALYSIS & INTERPRETATION

Experiment1
Plot a graph comparing the mass of the rock (X-axis) with the crater size (Y-axis) and find the mathematical relations between these two quantities. Make your observations based on the graph you created.

Experiment2
Plot a graph comparing drop height (X-axis) with crater size (Y-axis) and find the mathematical relations between these two quantities. Make your observations based on the graph you created.

CONCLUSION & EVALUATION (Doc. 4 - 5)

Communicate results of hypotheses 1, 2 and 3, how crater sizes are determined by the mass of an impactor and by the impact speed; furthermore, the circular shape of the impact crater does not depend on the meteor shape.
Each student should be able to explain and demonstrate the formation of a crater and predict how the sizes of craters depend on impact masses and impact height.
Furthermore, the teacher drops a bullet from the same height of **Experiment1** and measures the size of the crater keeping the value of mass hidden from the students. As a final evaluation students should be able to estimate the hidden mass using their graphs.

Teacher can use assess rubrics shared in “Student assessment in the 21st century” or the ASSESSES app. Students can use rubric for self-assessment.

REFERENCES

Documetns and materials shared in Stand Summer School 30 th June – 5th July 2024, Marathon Greece.
C. Benna, D. Gardiol, INAF, 2018.
Smith, R.; Eistrup, C., Impact Craters, astroEDU, 1641 doi:10.14586/astroedu/1641.

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Doc. 1- Step by step working sheet.

STEP 1 – USE MULTIMEDIA RESOURCES	
☐	See the photo of the crater on the rocky planets and satellites of our solar system.
☐	See the animation of the formation of an impact crater.
☐	See the video of the most famous fireballs impacting on Earth and their consequences.
☐	Read journal articles about Perseid meteor shower.
STEP 2 – START YOUR DISCUSSION WITH THE TEACHER	
☐	Have you ever seen a fireball? Write your answer on your notebook.
☐	What do you think about falling star? Do falling stars have origin from asteroids and comets? Write your answer on your notebook.
☐	Why do these bodies impact on the Earth and on the other planets and satellites of our Solar System? Write your answer on your notebook.
☐	Why does the Moon have much more craters than the Earth? Write your answer on your notebook.
STEP 3 – EXPERIMENT 1	
☐	Make a brief description of the first experiment on your notebook.
☐	Make your hypotheses for Experiment 1 and write them on your notebook.
☐	Fill the worksheet of the Experiment 1.
STEP 4 – EXPERIMENT 2	
☐	Make a brief description of the second experiment on your notebook.
☐	Make your hypotheses for Experiment 2 and write them on your notebook.
☐	Fill the worksheet of the Experiment 2.
STEP 5 – ANALYSIS & INTERPRETATION	
☐	Plot the data of Experiment 1 on a graph comparing the mass of the rock (x-axis) with the crater size (y-axis) and find the mathematical relations between these two quantities.
☐	Make your observations based on the graph you created.
☐	Plot the data of Experiment 1 on a graph comparing drop height (x-axis) with crater size (y-axis) and find the mathematical relations between these two quantities.
☐	Make your observations based on the graph you created.
STEP 6 – CONCLUSIONS	
☐	Communicate the results of your hypotheses. You can choose the communication method you prefer e.g. a multimedia presentation.
☐	Make a prevision of the hidden mass using your graph.
STEP 7 – EVALUATION. **Write a level for each of the following indicators using the rubric for self-assessment.**	
☐	Problem solving ________
☐	Reasoning and proof ________
☐	Communication ________
☐	Representation ________

Doc. 2 – Worksheet for Experiment 1.

Experiment 1 – Dropping height: ____________cm				
Nember of bullet	Note whether the bullet is rounded (R) or not (NR)	mass (g)	Diameter of the crater (cm)	Note (write if the impact created a crater; describe the shape of the crater, if is it circular or not; measure the depth of the crater).

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Doc. 3 – Worksheet for Experiment 2.

Experiment 2 – mass of the bullet: _____________g		
Dropping height (cm)	Diameter of the crater (cm)	Note (write if the impact mass created a crater; describe the shape of the crater, if is it circular or not; measure the depth of the crater).

Doc. 4 – Assessment rubric.

Indicators	Levels				
	1	2	3	4	5
Actively participating in discussion	Remains passive during discussions.	Struggles to participate in discussions.	Actively participates in discussions.	Participates constructively in discussions, contributing to rich shared reflections.	Participates constructively in discussions serving as a reference to others.
Showing critical spirit	Does not seem to question information, situations, or conditions of own life.	Visibly questions certain information and situations in own life.	Shows a critical attitude towards information received and the conditions of own life.	Explores and inquires the world around. Shows to be reflective about acquired information and own life.	Demonstrates to formulate personal judgements and evaluations based on systematic reflection.
Listening attentively	Does not seem to listen attentively. Tries to impose own ideas on others.	Appears to get distracted easily and does not seem to capture the entire message.	Shows focus and interest while listening to others.	Actively listens to others demonstrating to attempt full comprehension of others' ideas.	Actively listens to others while respecting their own time to show they are being listened to.
Asking questions to gain a better understanding.	Does not ask questions and seems to assume to have understood what others say.	Asks few questions in an inopportune or unstructured way.	Asks open questions as an effort to understand others' ideas and positions.	Asks questions that enable a natural flow, contributing to enlarge the conversation.	Formulates questions that improves the atmosphere or help the dialogue to move forward.
Expressing self clearly and accurately.	Self-expression is vague or unclear.	Expresses self hesitantly and without managing to convey ideas in a clear way.	Conveys ideas concisely when in familiar contexts.	Expresses ideas with ease and fluency in different contexts.	Shows a general outstanding easiness of self-expression and clear communication.
Identifying a problem and taking the decision to address it.	Does not seem to realize when a problem exists.	Realizes that a problem exists but struggles to concretely identify it.	Actively identifies problems but remains passive toward them.	Easily identifies problems and assumes a proactive attitude toward them.	Identifies problems, concretely explaining how they do it, and demonstrate a proactive attitude to address them.
Conveying important information.	Does not present ideas or expression	Presents some ideas.	Expresses well-reasoned ideas.	Conveys well-reasoned	Noteworthy for the clarity of expression

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	is poor and confused.			ideas, feeling and values.	related to reasoning and/or feelings.
Autonomous and self-regulated learning.	Does not show initiative in the learning process and follows teacher's proposals incompletely.	Completes teacher's proposals but with the least amount of effort.	Completes teacher's proposals with motivation and with effort to succeed.	Goes beyond teacher's proposals, completing tasks with additions that improve them beyond what is required.	Goes beyond teacher's proposals, aiming to explore the same or other topics further to learn more.
Use of mathematics language	No attempt is made.	Every day, familiar language is used to communicate ideas.	Some formal math language is used, and examples are provided to communicate ideas.	Formal math language is used throughout the solution to share and clarify ideas.	Precise math language and symbolic notations are used to consolidate math thinking and to communicate ideas.
Graphic representation	No attempt is made.	A partial attempt is made to construct a mathematical representation.	An attempt is made to construct a mathematical representation to record and communicate problem solving	An appropriate and accurate mathematical representation is constructed and refined to solve problems.	An abstract or symbolic mathematical representation is constructed to analyze relationships and to interpret phenomenon.

Doc. 5 - Self-assessment rubric for Students.

Indicators	Levels				
	1	2	3	4	5
Problem solving	I did not understand the problem.	I understand only part of the problem. My strategy works for part of the problem.	I understand the problem and my strategy works. My answer is almost correct.	I understand the problem and my strategy works. My answer is correct.	I understand the problem autonomously. My answer is correct and accurate.
Reasoning and proof	My math thinking is not correct.	Some of my math thinking is correct.	Almost of my math thinking is correct.	All of my math thinking is correct.	I showed that I knew more about a math idea that I used in my plan.
Communication	I used no math language and/or math notation.	I used some math language and/or math notation.	I used math language and/or math notation with some inaccuracies throughout my work.	I used math language and/or math notation accurately throughout my work.	I used a lot of specific math language and/or notation accurately throughout my work.
Representation	I did not use a math representation to help solve the problem and explain my work.	I tried to use a math representation to solve the problem and explain my work, but it is not completed.	I tried to use a math representation to help solve the problem and explain my work, but it has some mistakes in it.	I made a math representation to solve the problem and explain my work, and it is labeled and correct.	I made a math representation to solve the problem and explain my work autonomously, and it is correct, and accurate.

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