SIEMENS STEM DAY | Science Technology Engineering Math

3D PRINTING ROBOTS

OVERVIEW

Students will investigate the application of 3D printing to space technology. Students develop a conceptual framework for how 3D printer robots could be used to mine asteroids. Students analyze how their framework would enable more rapid and cost-effective exploitation of asteroid resources compared with a conventional mining approach.

THIS LESSON FOCUSES ON

Engineering Design Cycle	21st Century Skills
• Designing Solutions	• Critical Thinking

OBJECTIVES

Students will be able to:

- develop potential technological solutions to an engineering problem.
- analyze solutions to an engineering problem by using a cost-benefit approach.

MATERIALS

- Computer with Internet access
- Abundance of Asteroid Parts capture sheet
- Mining out of This World capture sheet

HAVE YOU EVER WONDERED...

- How will humans improve the quality of life while conserving resources on Earth? Population growth and improving quality of life require ever more resources. However, on a finite globe, such resources are limited, and extraction of resources can harm the environment.

3D PRINTING ROBOTS

- What are the limits to the complexity of things that can be made with 3D printing? Desktop printers can be used to create small toys or other useful objects. Engineers are working on ways to 3D print highly complex devices, even cars and other machines!

MAKE CONNECTIONS!

How does this connect to students?	How does this connect to careers?	How does this connect to our world?
Robotics and 3D printing are two of the fastest growing sectors in technology. Manufacturing has used industrial robots for decades. From automated surgery to self-driving cars, robots are assuming a central role in our lives. 3D printing is becoming mainstream as desktop printers become affordable. However, commercial applications range from art, jewelry and apparel to spare parts for planes and automobiles.	A **3D designer** implements a concept to create a feasible product. Designers may work on medical products, apparel, architectural models, and custom products such as prototypes for mass production. A **3D printing technician** processes, cleans, and finishes parts produced during the printing process. Other responsibilities may include maintenance and repair of 3D printers. A **robotics engineer** designs, supervises and tests robotic devices. This role includes analyzing designs for safety, reliability, and aesthetics. A **robotics software developer** works with the engineering team to optimize the robot for its intended function. The developer writes the necessary software that ensures the hardware operates efficiently and safely.	As global population grows, the demand on mineral resources will grow. However, obtaining and using such resources impact the environment. To minimize the environmental impacts, scientists propose that we exploit the mineral riches of asteroids. Most of the technical challenges have been overcome. Scientists believe that with a combination of 3D printing technology and robotics, asteroids can provide a wide range of minerals at unprecedented low cost and with minimal environmental impact.

Please allow for more classroom time if you want students to further explore careers.

3D PRINTING ROBOTS

BLUEPRINT FOR DISCOVERY

1. Ask students to write down their best guess of the cost of water (e.g., a gallon of tap water costs less than 1 cent, whereas bottled water may cost about $7.50 a gallon[1]).

   Then, ask students to consider how much it could cost to take a bottle of water to the International Space Station.

   Share with students, that according to one estimate, the cost of taking a bottle of water to the International Space Station ranges from $9,100 to $43,180[2]. Resources are very expensive to transport for space travel and scientists and engineers are looking for new ways to extract resources on the go instead of packing and bringing them on expeditions.

2. Guide students to read **Abundance of Asteroids Part I capture sheet** for students to review the three types of asteroids. Students will be asked to identify which type of asteroid would most likely include water. Use the **Abundance of Asteroids Part II capture sheet** and ask students to estimate the value of water. Review the correct answer. Ask students to consider what this value means to us on Earth and the value in space. Display the quote, "Price is what you pay. Value is what you get." Guide students to share out how that applies to the calculations they completed.

   Anticipated answer:
   A C-type asteroid, may be comprised of up to 22% water[3]. There are around 25 million asteroids with a diameter of 100 meters. The volume of such an asteroid (assuming it is spherical) is around 5.24×105 cubic meters. A C-type asteroid of this size would therefore contain around 115,280 cubic meters of water. Assuming a bottle of water is 500 milliliters (0.5 liters), water's value (based on cost of transport to the ISS) is $18,000 to $86,360 per liter. There are 1000 liters in a cubic meter of water. Therefore, 1 cubic meter of water is worth $18,000,000 to $86,360,000. Thus, the value of water in a small asteroid could be from 2.075×10^{12} to 9.956×10^{12} dollars. That is between 2 to 10 trillion dollars. This calculation involves several assumptions. However, it shows that the value of asteroids is immense, even if considering something as mundane as water.

3. Next, invite each group to choose an element from the following list and record their element using the **Mining out of This World capture sheet:**

   - gold
   - iridium
   - paladium
   - platinum
   - rhenium

3D PRINTING ROBOTS

- rhodium
- ruthenium
- titanium

Read the following information to the class:

Scientists estimate that mining just one asteroid 500 meters across will yield a greater quantity of the platinum-group metals than the total mined throughout history.[4] *Such a significant source of rare metals could drive further technological advances since products that rely on such metals (e.g., electronics) will suddenly become dramatically cheaper. For example, ruthenium is used in solar cells.*[5]

Guide students to research the use and value of their chosen element.

4. Student groups will then compare mining techniques on Earth to remote mining asteroids. Groups should research innovative approaches to using robotic mining machines. Robotic mining machines may include 3D printing capabilities for repairs, assembly, and/or to create new machines once on the asteroid. Groups will summarize their thinking by comparing the efficiency of this approach with that of using astronaut miners.

Take action!
Students can explore the technology and economics of asteroid mining further.
http://www.philipmetzger.com/blog/type-of-asteroid-to-mine-part-1/
http://www.bbc.com/news/science-environment-25716103
http://www.nature.com/news/space-miners-seek-riches-in-nearby-asteroids-1.10513
http://ssi.org/2010/SM14_presentations/101030_SSI_Blair-Gertsch.pdf
http://kesellc.com/?q=system/files/KESE-LLC_Cornucopia%20Mission%20Paper.pdf
https://www.saimm.co.za/Journal/v114n12p1039.pdf
http://www.astronomysource.com/2012/08/21/asteroid-mining-2/

3D PRINTING ROBOTS

NATIONAL STANDARDS

Science	Next Generation Science Standards HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
Technology Education	International Technology and Engineering Educators Association 2.Z Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste. 3.G Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function. 3.H Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields. 13.L Use assessment techniques, such as trend analysis and experimentation, to make decisions about the future development of technology. 20.K Structures are constructed using a variety of processes and procedures.
Mathematical Practice	Common Core CCSS.MATH.CONTENT.HSN.Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. CCSS.MATH.CONTENT.HSA.CED.A.3 Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context.

3D PRINTING ROBOTS

ABUNDANCE OF ASTEROIDS

Part I

- C-type asteroids include a large amount of carbon and account for 75% of all known asteroids.
- S-type asteroids consist mainly of iron and magnesium-solicates. They make up approximately 17% of asteroids.
- M-type asteroids can contain nickel-iron while others are more uncertain. They are the third most common asteroid type.

Which type of asteroid would most likely be comprised of water?

Part II

_________ asteroid may be comprised of up to 22% water. [6]

There are around 25 million asteroids with a diameter of 100 meters. The volume of such an asteroid (assuming it is spherical) is around 5.24×105 cubic meters. A C-type asteroid of this size would therefore contain around 115,280 cubic meters of water. Assuming a bottle of water is 500 milliliters (0.5 liters), water's value (based on cost of transport to the ISS) is $18,000 to $86,360 per liter. There are 1000 liters in a cubic meter of water.

How much is 1 cubic meter or water worth?

What is the overall value of water in a small asteroid?

3D PRINTING ROBOTS

Mining out of This World

Use of element on Earth and value:			
Conventional mining technique on Earth (overview):			
Equipment, tool, or process	Equipment, tool, or process	Equipment, tool, or process	Equipment, tool, or process
What are components a 3D printer or robot could potentially do?	What are components a 3D printer or robot could potentially do?	What are components a 3D printer or robot could potentially do?	What are components a 3D printer or robot could potentially do?
Would you recommend using robotics and 3D printing to mine this element? Or would you explore astronaut miners? Support your response with evidence from your research and include qualitative and quantitative data.			

3D PRINTING ROBOTS

Cited Works

[1] Boesler, Matthew. Bottled Water Costs 2000 Times As Much As Tap Water. July 12, 2013 http://www.businessinsider.com/bottled-water-costs-2000x-more-than-tap-2013-7

[2] Kramer, Sarah and Mosher, Dave. Here's how much money it actually costs to launch stuff into space. July 20, 2016 http://www.businessinsider.com/spacex-rocket-cargo-price-by-weight-2016-6

[3] Shaw, Stephen. Posts Tagged 'C-type asteroids' Asteroid Mining. August 12, 2012 http://www.astronomysource.com/tag/c-type-asteroids

[4] Lovett, Richard A. Space miners seek riches in nearby asteroids. April 24, 2012 http://www.nature.com/news/space-miners-seek-riches-in-nearby-asteroids-1.10513

[5] Royal Society of Chemistry. Periodic Table: Ruthenium http://www.rsc.org/periodic-table/element/44/ruthenium

[3] Shaw, Stephen. Posts Tagged 'C-type asteroids' Asteroid Mining. August 12, 2012 http://www.astronomysource.com/tag/c-type-asteroids