THE MATHEMATICAL ASSOCIATION OF VICTORIA

VSSEC

TEACHER NOTES

MATHEMATICS IN CAREERS

Investigation - Bone Mineral Density (BMD) in Astronauts

Key career focus for this investigation: Health and biomedical sciences
Related career areas: Space sciences

Image by Gerd Altmann, Pixabay.

THINKING ABOUT CAREERS

- Brainstorm health professions you can think of where maths is frequently used.
  Use https://joboutlook.gov.au/ to explore health related career pathways that include use of mathematics.
  How is maths used in these scenarios? What maths is used in these scenarios?
- This task focuses on how maths is used in Health Sciences, through investigating Bone Mineral Density (BMD). A decrease in BMD can lead to health issues and diseases such as osteoporosis. The tasks specifically looks at BMD in astronauts.
- Explore careers such as Radiologists and physiotherapists to discover how maths is used in these. For a more extensive list of careers related to this task, with a maths / science focus, refer to the table at the end of the task and explore the maths used in these jobs.

MATHEMATICS IN EVERYDAY LIFE AND CAREERS

Mathematical focus for this investigation

- Use appropriate methods to sort, organise, and manipulate data
- Create graphs to show patterns in data
- Explore the connection between algebraic and graphical representations of relations

Scientists including health professionals model relationships comparing different scenarios. The relationship may be linear or other. They graph data and compare the graphs, changing one variable to see the effect on the other to test hypothesis.

- Linear equations use one or more variables where one variable is dependent on the other.
- Many people use linear equations every day, even if they do the calculations in their head without drawing a line graph.
- Brainstorm and share scenarios where this mathematics may be used in health and biomedical science and space sciences to solve problems.

MATHEMATICAL INVESTIGATION - BONE MINERAL DENSITY (BMD) IN ASTRONAUTS

TEACHER INFORMATION

LINKS TO VICTORIAN CURRICULUM

Mathematics links to Victorian Curriculum Level 10	Application to work and life
Linear and non-linear relationships Solve problems involving linear equations, including those derived from formulas (VCMNA335) Explore the connection between algebraic and graphical representations of relations such as simple quadratic, reciprocal, circle and exponential, using digital technology as appropriate (VCMNA339)	Scientists model relationships comparing different scenarios. The relationship may be linear or other. They graph data and compare the graphs, changing one variable to see the effect on the other to test hypothesis. Linear equations use one or more variables where one variable is dependent on the other. Many situations where there is an unknown quantity can be represented by a linear equation, such as working out income over time, calculating mileage rates, or predicting profit. Many people use linear equations every day, even if they do the calculations in their head without drawing a line graph. Other situations can be modelled by exponential equations, examples of this may include population increase, virus growth.
Mathematics links to Victorian Curriculum Level 10A	**Application to work and life**
Solve simple exponential equations (VCMNA360)	As above.
Further example of other maths used Percentages, exponential notation	As above.

PROFICIENCY FOCUS: VICTORIAN CURRICULUM

This investigation focuses on: Fluency, Reasoning, Problem Solving		
Fluency describes students developing skills in choosing appropriate procedures, carrying out procedures flexibly, accurately, efficiently and appropriately, and recalling factual knowledge and concepts readily. This investigation focuses on: • Accurately and efficiently recording and organising data • Choosing appropriate tables and graphs for displaying data	**Reasoning** refers to students developing an increasingly sophisticated capacity for logical, statistical and probabilistic thinking and actions, such as conjecturing, hypothesising, analysing, proving, evaluating, explaining, inferring, justifying, refuting, abstracting and generalising. This investigation focuses on: • Explaining their thinking • Deduce and justify strategies used and conclusions reached • Making inferences about data	**Problem Solving** is the ability of students to make choices, interpret, formulate, model and investigate situation, select and use technological functions and communicate solutions effectively. This investigation focuses on: • Using mathematics to represent unfamiliar or meaningful situations

MATHEMATICAL INVESTIGATION - BONE MINERAL DENSITY (BMD) IN ASTRONAUTS

STUDENT INVESTIGATION WITH TEACHER GUIDE

INVESTIGATION BACKGROUND

The decrease in bone density during space travel and its effects on long term space deployment are of great concern to mission specialists. A normal human on earth experiences a 1% decrease in bone mineral density (BMD) per year from after the age of 30. An astronaut in space may experience a BMD decrease of 1% per month!

Mathematical focus for this investigation

- Use appropriate methods to sort, organise, and manipulate data
- Create graphs to show patterns in data
- Explore the connection between algebraic and graphical representations of relations

STUDENT INVESTIGATION

Your task is to model the relationship between BMD readings on earth and their corresponding readings from space. To assist you in your calculations and modelling the tables below (see Tables 1 and 2 provided by VSSEC) provide Astronaut BMD data for three astronauts.

Expected BMD data for a 5 year period if NOT going into space.

Mission (Time in years)	Astronaut 1 BMD	Astronaut 2 BMD	Astronaut 3 BMD
0	1050	1500	1250
1	1039.5		
2	1029.11		
3	1018.81		
4	1008.63		
5	998.54		

Table 1: Initial BMD data and BMD calculations for a 5-year period on Earth.

MATHEMATICAL INVESTIGATION - BONE MINERAL DENSITY (BMD) IN ASTRONAUTS

Expected data during time on Space Station (table for a 6 month period).

Time on ISS (Time in days)	Astronaut 1 BMD	Astronaut 2 BMD	Astronaut 3 BMD
0 (start)	1050	1500	1250
30 (1 month)	1039.5		
45			
60 (2 months)	1029.11		
75			
90			
105			
120			
135			
150			
165			
180	985.55		

Table 2: Initial BMD data and expected BMD calculations during time on International Space Station (ISS). (Note: data represents a 6-month period).

PART 1

Complete Table 1 finding the expected BMD measurements for astronauts 1, 2, and 3, for a 5 year period, assuming they are **not** going to space in this time. Use the data from your table to find a relationship or mathematical equation that models the BMD decrease in the 3 astronauts over the 5 years. Demonstrate your relationship with a graph.

PART 2

Complete Table 2 finding the expected BMD measurements for astronauts 1, 2, and 3, for the 6 month period, when they are on the space station. Use the data from your table to find a relationship or mathematical equation that models the BMD decrease in the 3 astronauts over the 6 month period. Demonstrate your relationship with a graph.

PART 3

How long would the astronauts returned to earth need to recover their BMD to original readings?

PART 4

Provide a summary of your findings, showing how the relationship you have modelled explains your reasoning and understanding.

MATHEMATICAL INVESTIGATION - BONE MINERAL DENSITY (BMD) IN ASTRONAUTS

REFERENCE MATERIAL

https://www.nasa.gov/mission_pages/station/research/benefits/bone_loss.html

https://en.wikipedia.org/wiki/Osteoporosis#/media/File:615_Age_and_Bone_Mass.jpg

ENABLING PROMPTS

Using the set of astronaut BMD data provided by VSSEC, you will need to:

- Create your own databases based on the measurements obtained from the initial data given, by completing tables 1 and 2
- Develop linear equations to describe the relationships
- Write down the general equation of a linear function.
- Graphing the data developed.

$y = mx + c$

In the case of Astronauts, since decrease of 1% or 0.01

$A_nBMD = -0.01t + \text{initial } BMD$

In all cases let t = time. Prior to going tinto space, t denotes 1 year

$A_1BMD = -0.01t + 1050$ since this is a constant change can be written as $A_1BMD = 1050(1 - 0.01)^t$

$A_2BMD = -0.01t + 1050$ since this is a constant change can be written as $A_2BMD = 1500(1 - 0.01)^t$

$A_3BMD = -0.01t + 1050$ since this is a constant change can be written as $A_3BMD = 1250(1 - 0.01)^t$

During time on Space Station, t denotes 1 month

$A_1BMD = 1050(1 - 0.01)^t$

$A_2BMD = 1500(1 - 0.01)^t$

$A_3BMD = 1250(1 - 0.01)^t$

EXTENSION OR ADVANCED INVESTIGATION

An astronaut travelling to Mars and back would be expected to be travelling through space for up to 2 and half years. Plot their BMD loss over this period of time.

It has been considered that sending older astronauts (50 years) to Mars might be a more advantageous proposition, as they will have accrued a great deal of experience and specialist training, as well as being less susceptible to certain types of cancers. Using the image Age_and_Bone_Mass, can you plot BMD for a male and female individual both on Earth and in space and make predictions of BMD loss in male and female astronauts of this age travelling to space?

Using this information could you create a model to predict bone density loss on planets with differing gravity?

MATHEMATICAL INVESTIGATION - BONE MINERAL DENSITY (BMD) IN ASTRONAUTS

CAREERS RELATED TO THIS INVESTIGATION

Refer to the student investigation, it provides:
- An extensive table of careers related to this investigation
- Further career references

CAREERS ACTIVITIES

Refer to the student investigation, it provides:
- A table of the top 10 rated jobs of 2021. This data comes from careercast.com. Have students investigate the jobs specific to this investigation.

INDUSTRY PARTNER

This project was produced collaboratively between The Mathematical Association of Victoria (MAV) and the Victorian Space Science Centre (VSSEC).

The Victorian Space Science Education Centre (VSSEC) is a specialist STEM learning facility, one of six established by the Victorian State Government. Since its official opening in 2006, VSSEC has used the context of space to enhance the learning experiences in Mathematics, Science, Technology and Engineering for both teachers and students.
VSSEC is located in the grounds of Strathmore Secondary College. The spiral galaxy shaped building provides a stimulating environment which encourages students to be fully engaged in problem-solving and scenario-based learning.
www.vssec.vic.edu.au