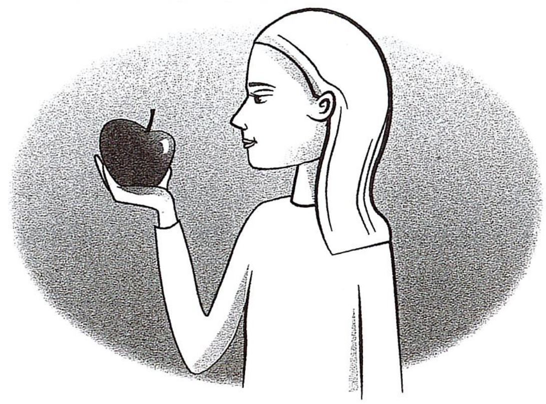
Atoms and Apples



Seven friends were talking about the size of atoms. They wondered how the width (diameter) of a large atom compares to the width (diameter) of an apple. They each used a different analogy. This is what they said:

Ari: I think it is like comparing the width of an apple to the width of a cell.

Karen: I think it is like comparing the width of an apple to the width of a basketball.

Carlo: I think it is like comparing the width of an apple to the length of a school bus.

Paisley: I think it is like comparing the width of an apple to the length of a football field.

Greg: I think it is like comparing the width of an apple to the width across the Pacific Ocean from Los Angeles to China.

Dagmar: I think it is like comparing the width of an apple to the diameter of Earth.

Feng: I think it is like comparing the width of an apple to the diameter of the Sun.

Who do you think used the best analogy? ____________________ Explain your thinking.

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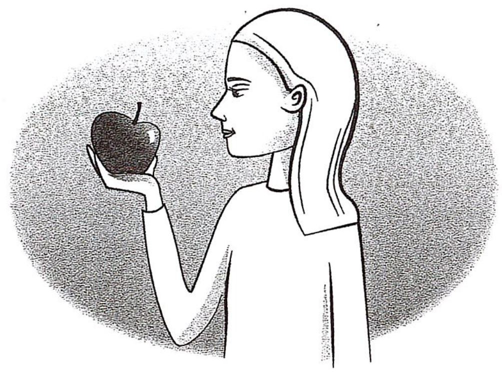
Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about the size (in diameter) of atoms. The probe is designed to reveal how students use the crosscutting concept of scale to compare relative sizes by estimating size in general and using orders of magnitude.

Type of Probe

Friendly talk

Related Concepts

Atom, relative size, scale

Explanation

The best answer is Dagmar's: "I think it is like comparing the width of an apple to the diameter of Earth." Atoms are extremely small. They range in diameter (twice the atomic radius) from a small atom such as hydrogen with a diameter of about 0.2 nanometers to a large atom such as barium with a diameter of about 0.7 nanometers. One nanometer is equal to 10^{-9} meters and one meter equals 10^{9} nanometers. One million average-size atoms placed end to end would barely cover the width of the period at the end of this sentence. To visualize extremely small sizes such as the size of an atom, it helps to use a conceptual model such as an analogy to compare relative scale sizes.

For the sake of simplifying the calculation, if you rounded off the diameter of a large atom to 1 nanometer (10^{-9} m) and could zoom the atom up to the size of an apple (diameter about 10^{-1} m), you would expand it 10^{8} times, or make it 10 times bigger 8 consecutive times: (10^{-9} m)(10^{8}) = 10^{-1} m. You can do the same to the apple, using the same expansion factor: (10^{-1} m)(10^{8}) = 10^{7} m, or 10,000 km. This is close to the diameter of the Earth, which is about 12,000 km.

Administering the Probe

This probe can be used with students in grades 6–12. You may need to explain the analogy to students. One way is to say *if an atom were the width (or diameter) of an apple, then an apple would be the width (or diameter) of* ____. You may need to clarify the measurement terms, using either width or diameter, and show students an apple to visualize the measurement of width. If students struggle with size measurements of the less familiar objects, you can provide actual measurements for each of those answer choices.

Related Disciplinary Core Ideas and Crosscutting Concepts From the *Framework* (NRC 2012)

3–5 PS1.A: Structure and Properties of Matter

- Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means.

6–8 Crosscutting Concept: Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

9–12 Crosscutting Concept: Scale, Proportion, and Quantity

- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

Related Research

- Students may understand that an atom is too small to be seen with the unaided eye, yet they may believe it can be seen with a very powerful microscope (Harrison and Treagust 1996).
- Early studies of students' ideas about the size of atoms and molecules show that although students know that an atom or molecule is the smallest structural unit of a substance, they often have difficulty comprehending the minuteness of atoms and molecules (Driver et al. 1994).
- A study of middle school students found that some students thought they could see atoms or molecules under a regular optical microscope in the same way they could see microbes (Nakhleh, Samarapungavan, and Saglam 2005).

Suggestions for Instruction and Assessment

- This probe supports three-dimensional assessment and learning. The probe combines a concept (the idea that atoms are very small) with the crosscutting concept of scale and proportion (in dimension) and the scientific practice of developing and using a model (making an analogy).
- The classic 1977 Eames film *Powers of Ten* can be used to develop a sense of scale and relative sizes from a carbon atom to the edge of our known universe: *www.eamesoffice.com/the-work/powers-of-ten.*
- High school students can be challenged to use the scientific practice of using mathematics and computational thinking by using powers of 10 and ratio and proportion to explain the comparison of the size of an atom with an apple. Students can compare their calculation and explanation with that of Richard Feynman's shown on the following Annenberg web page: *www.learner.org/courses/essential/physicalsci/session2/closer2.html.*
- Challenge students to come up with other scaling analogies. For example, if an atom were the size of a grain of salt, then the grain of salt would be the size of a ____.
- Some students confuse the size of atoms with cells. Part of this confusion comes from knowing that both atoms and cells have a nucleus; therefore, students may reason that they are about the same size. The probe "Cells and Size" (available in Keeley, Eberle, and Dorsey 2008) can be used to uncover this common misunderstanding.

References

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Nakhleh, M., A. Samarapungavan, and Y. Saglam. 2005. Middle school students' beliefs about matter. *Journal of Research in Science Teaching* 42 (5): 581–612.

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