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Physical Science and Nature of Science Assessment Probes

Life, Earth and Space Science Assessment Probes

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Thermometer

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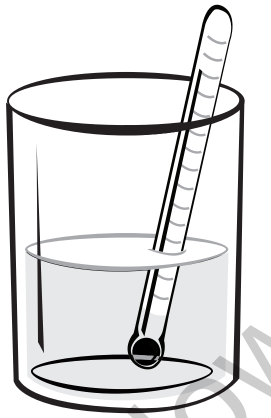

Purpose

The purpose of this assessment probe is to elicit students' ideas about thermal expansion. The probe is designed to find out whether students attribute expansion of the space between molecules to the rise of the liquid in a thermometer.

Related Concepts

kinetic molecular theory, thermal expansion, thermometer

Explanation

Molly has the best answer: A thermometer is a closed system. It operates on the principle that the fluid inside it (usually alcohol or mercury) expands when heated and contracts when cooled. When the bulb is in contact with a warm object such as the hot water, energy from the hot water is transferred to the liquid inside the bulb. The molecules of the red liquid, in this case alcohol with a red dye added, gain energy and increase their motion as the faster moving molecules bump up against and push the slower moving molecules. This causes the molecules to move further apart, and as a result, the alcohol inside the thermometer occupies more space as it expands. In order to occupy more space, the alcohol has to rise in the narrow tube. It is this increased motion and collisions of the molecules inside the very narrow tube that accounts for the rise of the alcohol.

Curricular and Instructional Considerations

Primary Students

At the primary school level, students use thermometers to measure the temperature of objects and materials. At this year level they are developing the procedural skills of using a thermometer. They are not expected to know how a thermometer works.

Middle Years Students

At the middle years level, students continue to use thermometers. They learn how a thermometer works and should be able to explain how it operates at a substance level – most substances expand or contract when they are heated or cooled. Some students can begin to use particle ideas to explain why a substance expands when heated and contracts when cooled and connect that to what happens inside a thermometer. At this stage they also recognise water as an anomaly to the idea that substances expand when heated and contract when cooled, noting that when water cools to form ice, it expands.

High School Students

At the high school level, students deepen their understanding of kinetic molecular theory and relate the thermometer phenomenon to particle ideas about thermal expansion. At this year level, they are expected to be able to explain how a thermometer works based on the expansion or contraction of the liquid due to increasing or decreasing space between the molecules as a result of increased or decreased motion when energy is gained or lost by the molecules.

Administering the Probe

This probe can be demonstrated for students using a red alcohol thermometer or performed in small groups with appropriate safety precautions. The word *volume* is intentionally not used to describe the "liquid going up" in order to probe for younger students' ideas related to the visible increase in the height of the liquid without having their lack of understanding of what volume is interfering with their ideas about the phenomenon. For middle years and high school students who understand the concept of volume, you can replace "His students disagreed about why the red liquid in the thermometer rose when the thermometer was placed in hot water" with "…why the volume of red liquid in the thermometer increased when the thermometer was placed in hot water."

Related Ideas in the *F–10 Curriculum: Science* Content Descriptions (ACARA 2014a)

Foundation Year Chemical Sciences

- Objects are made of materials that have observable properties (ACSSU003)

Year 3 Physical Sciences

- Heat can be produced in many ways and can move from one object to another (ACSSU049)

Year 3 Planning and Conducting

- Safely use appropriate materials, tools or equipment to make and record observations, using formal measurements and digital technologies as appropriate (ACSIS055)

Year 5 Chemical Sciences

- Solids, liquids and gases have different observable properties and behave in different ways (ACSSU077)

Year 5 Planning and Conducting

- Use equipment and materials safely, identifying potential risks (ACSIS088)

Year 8 Physical Sciences

- Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems (ACSSU155)

Related Ideas in the *Senior Secondary Curriculum: Physics* Content Descriptions (ACARA 2014e)

Unit 1 Heating Processes

- Heat transfer occurs between and within systems by conduction, convection and/or radiation (ACSPH016)
- The kinetic particle model describes matter as consisting of particles in constant motion, except at absolute zero (ACSPH017)
- All systems have thermal energy due to the motion of particles in the system (ACSPH018)
- Two systems in contact transfer energy between particles so that eventually the systems reach the same temperature; that is, they are in thermal equilibrium (ACSPH022)

Related Research

- Some students tend to regard liquids as continuous (non-particulate) and static (Driver et al. 1994).
- In an Australian study of 25 children ages 8–11, children were asked how they thought a thermometer worked (Appleton 1985). About one-third of the children suggested the thermometer "was sensitive to heat", or that it "was made to go to the right number". Other suggestions involved pressure, pushing or heat rising (Driver et al. 1994).

Suggestions for Instruction and Assessment

- Have students research how to make a thermometer and then have them build one. Students should demonstrate the use of their thermometers and explain how they work at a substance level and a particle level (if they are ready to use atomic/molecular reasoning).
- Use the rising level of liquid in a thermometer as a plausible phenomenon to develop the idea that most substances expand when heated.
- Trace the transfer of thermal energy in a thermometer from the hot water to the glass to the alcohol. Have students draw a visual representation of the transfer of energy between molecules.
- Have students draw pictures to show what happens to the liquid in a thermometer at the particle level when the bulb comes in contact with hot material. Use the drawings (whiteboards work well for this) to discuss students' ideas about conduction, the particle nature of matter and kinetic molecular theory.
- Use the analogy of playing pool to illustrate what happens when molecules collide and transfer energy. When a pool cue ball hits a rack of pool balls, it transfers energy and the balls it hits spread out.
- Help the students who chose Jonathan's response to understand how some words in

science are used incorrectly. For example, the common phrase "heat rises" is incorrect. It is the warm fluid (air or water) that rises, not the heat.

- Probe students' reasoning further for each of the distracters chosen and challenge their ideas. For example, Greta's idea can be challenged with conservation of matter reasoning, including the idea of a closed system in which no additional molecules can get into the thermometer.
- Relate expansion of the liquid in a thermometer to expansion of a metallic object. A metal ball and ring apparatus, available through most science supply shops, demonstrates how a metal expands when heated by showing how the ball passes through the ring before the ball is heated, but not after it is heated. Have students connect this phenomenon to what happens inside the thermometer.

Related Resources

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Does It Have a Life Cycle?

Teacher Notes

Purpose

The purpose of this assessment probe is to elicit students' ideas about life cycles. The probe can be used to determine whether students recognise that although life cycles vary in length and developmental stages, all multicellular organisms go through a life cycle.

Related Concepts

development, growth, life cycle, living vs. non-living, reproduction

Explanation

All of the organisms on the list go through a life cycle. The entire lifespan of an organism, including the birth of a new generation of offspring, is called a *life cycle*. A life cycle typically includes fertilisation and development of the embryo or embryo-like stage, birth or emergence, growth and development into an adult, reproduction and death of the adult. It is cyclic because most adult organisms reproduce and give rise to new offspring which keep the cycle going. At some stage in the life cycle of multicellular organisms, they stop reproducing and eventually die.

Stages of the life cycle vary among different types of organisms. For example, some organisms undergo changes during their early development in which the developing organism looks very different from the adult (e.g. butterfly, frog, beetle). Other organisms give rise to offspring with developing features that are similar to adult features (e.g. shark, human, tree, cow). Some life cycles are short (measured in days) and some are long (measured in years). Other differences include details of fertilisation and zygote development.

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Curricular and Instructional Considerations

Primary Students

Primary school students observe a variety of living organisms in the classroom to learn about their life cycles. Direct experiences include raising butterflies, frogs and plants to study their life cycles. Representations are often used to sequence life cycles and to compare and contrast different types of cycles, such as complete and incomplete metamorphosis in insects. Studying the life cycle of an organism helps children understand the continuity of life.

Middle Years Students

In the middle years, students learn about fertilisation (including pollination) as the beginning of an animal or plant's life cycle. Changes in the development of a plant or animal embryo are examined, including similarities between development of different species of plant or animal embryos. Details of human reproduction and development are introduced at the middle years level. At this level, students begin to link the idea of cell division to growth of an organism.

High School Students

In high school, biology students build on their basic F–8 understanding of sexual reproduction and development to focus on the haploid and diploid cellular details. They learn about complex life cycles of certain types of animals, fungi and vascular and non-vascular plants, including alternation of generations (alternation of sexual and asexual reproduction) and sexual variations, such as parthenogenesis (development of an organism from an unfertilised egg), changing from male to female or vice versa and hermaphrodism (having both male and female reproductive organs).

Administering the Probe

For younger students, you may choose to reduce the number of organisms on the list and/or include pictures of each. Remove any organisms on the list that students may be unfamiliar with. Consider adding additional items that students may have encountered in their local environment. This probe could be used with a card sort: have students group items into those with life cycles and those without, and listen carefully to their reasoning. Extend the probe even further by asking students to describe the stages of the life cycle for each item they select. Listen carefully for indications that students recognise a cyclic process that includes being born, reproduction and death, and do not just focus on the features of the developmental change each organism on the list goes through.

Related Ideas in the *F–10 Curriculum: Science* Content Descriptions (ACARA 2014a)

Year 2 Biological Sciences

- Living things grow, change and have offspring similar to themselves (ACSSU030)

Year 4 Biological Sciences

- Living things have life cycles (ACSSU072)

Year 8 Biological Sciences

- Multi-cellular organisms contain systems of organs that carry out specialised functions that enable them to survive and reproduce (ACSSU150)

Year 10 Biological Sciences

- The transmission of heritable characteristics from one generation to the next involves DNA and genes (ACSSU184)

Related Ideas in the *Senior Secondary Curriculum: Biology* Content Descriptions (ACARA 2014b)

Unit 3 DNA, Genes and the Continuity of Life

- Continuity of life requires the replication of genetic material and its transfer to the next generation through processes including binary fission, mitosis, meiosis and fertilisation (ACSBL075)

Related Research

- In a study that investigated 10- to 14-year-old children's ideas about the continuity of life, most could correctly sequence pictures of seed germination, but 66 per cent did not view the seed as alive and 19 per cent did not understand the continuity of life from seed to seedling (Driver et al. 1994, p. 49).
- Some studies indicate that children fail to consider death as part of a life cycle (Driver et al. 1994).
- As students investigate the life cycles of organisms, teachers might observe that young children do not understand the continuity of life from, for example, seed to seedling or larvae to pupae to adult (NRC 1996, p. 128).
- Some F–8 students tend to equate life cycles only with the examples they observed in school such as certain types of plant, butterfly, frog or mealworm life cycles or organisms that are similar to those they studied. When students encounter organisms that are different from the ones they studied, they fail to recognise that all organisms have a life cycle (Authors' analysis of student work).

Suggestions for Instruction and Assessment

- When students make observations of a particular plant or animal's life cycle, be explicit in developing the generalisation that all animals and plants go through a life cycle, even though details of their cycles differ.
- Use the term *continuity of life* along with *life cycle* so that the bigger idea of life continuing from generation to generation is emphasised. Teaching the stages in the life of different organisms is part of the idea of life cycles but can overshadow the more important idea of continuity if not explicitly addressed.
- Observe directly, if possible, or provide multiple visual examples of life cycles that differ in details. Have primary

school students identify the common pattern of birth, growth and development, reproduction and death. Have middle years and high school students identify fertilisation, embryo development, birth or emergence, growth and development, reproduction, aging and death.

- Avoid linear representations of life cycle stages that do not imply a cyclic process. Representations used should portray the continuity of life.
- So that students do not develop the misconception that life cycles begin after an egg hatches, a seedling emerges or an animal gives birth, explicitly target the idea that seeds and eggs are alive and that there is a developing organism inside some animals.
- Emphasise the diversity among species in the details of their life cycles while pointing out the commonalities, not only between different animal species or different plant species, but between animal and plant species as well. Provide opportunities throughout students' F–12 experiences to examine a variety of life cycles, including organisms they may not be as familiar with.

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