Instructionally Supportive Accountability Tests in Science: A Viable Option?

Design Team

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Components of the Report

- Section I: Nature of an Instructionally Supportive Accountability System
- Section II: Proof of Concept - Instructionally Supportive Accountability Tests in Physical Science
- Section III: Illustrative RFP Language for NCLB Science Test Proposals
- Conclusion: Is it feasible?

Building Tests To Support Instruction and Accountability

A Guide for Policymakers

Core Requirements

- According to the Commission, an instructionally supportive accountability test:
  - measures a modest number of significant curricular aims,
  - provides clear descriptions of what's to be assessed, and
  - supplies instructionally informative results to teachers, students and students' parents

Significant Curricular Aims

- In an effort to avoid overwhelming teachers with myriad content standards, an instructionally supportive accountability test should measure only a handful of curricular aims.

- Those few curricular aims must be genuinely significant.

- An example of such a significant curricular aim would be a content standard in language arts calling for students to be able to compose original narrative, descriptive, expository, or persuasive essays. This curricular aim, all by itself, describes a powerful and *measurable* student skill.

Clarified Descriptions

- Each of the important curricular aims must be described so that teachers can acquire a meaningful understanding of each skill or body of knowledge to be assessed.

- Any descriptions of the skills or knowledge to be assessed must be provided in a manner such that teachers will be willing to read those descriptions.

- Thus, the *assessment descriptions* accompanying each to-be-measured content standard (or benchmark, etc.) must be relatively brief, written in straightforward language, and must include one or more illustrative test items

Instructionally Informative Reporting of Results.

- Students' performances are reported in such a manner that a student's mastery of each assessed curricular aim can be determined in a reasonably accurate manner.
  - What the Commission was asking for was not perfect, unerring determination of students' mastery of each assessed curricular aim. To provide such precise estimates of a student's accomplishments would require the use of far too many items per assessed curricular aim.
- The Commission's members wanted to provide teachers, students, and students' parents with at least a fairly accurate idea about whether students had or hadn't mastered each curricular aim being tested.
  - The Commission rejected the idea of testing a student's mastery of a particular curricular aim with one or two test items (too few to yield any sensible estimate of mastery) or 25-30 test items (too many to permit the assessment of more than one or two curricular aims).

Commission's 9 Requirements

- **Requirement 1. *Prioritized Content Standards***
- **Requirement 2*. Unambiguously Described Content Standards***
- **Requirement 3. *Standard by Standard Reporting***
- Requirement 4. *Classroom Assessments of State Content Standards*
- Requirement 5*. Monitoring Curricular Breadth*
- Requirement 6*. Appropriate Assessment for all Students*
- Requirement 7. *Sufficient Test Development Time*
- Requirement 8. *Pertinent Professional Development*
- Requirement 9*. Ongoing Evaluation of the System*

Design Team Task

Determine whether the kinds of science tests called for in NCLB could be developed in accord with the Commission's conception of instructionally supportive accountability tests.

Starting point is what NCLB expects for a state's science tests, such assessments to be installed no later than the 2007-08 academic year.

NCLB Requirements

- States must have challenging academic content standards in science. Science content standards may be grade-specific, cover more than one grade, or may be course-specific at the high school level.

- States must administer science assessments, which are to be aligned with the state's science standards and involve multiple up-to-date measures of student academic achievement, including measures that assess higher-order thinking skills and understanding, at least once each in grades 3-5, 6-9, and 10-12.

NCLB Requirements (cont)

- Assessments may include either (or both) criterion-referenced assessments or augmented norm-referenced assessment. The assessments may be comprised of a uniform set of assessments statewide or a combination of state and local assessments.

- At least three achievement levels should be specified (e.g., basic, proficient, and advanced).

NCLB Requirements (cont)

- The same assessment system should be used to measure the achievement of all children, and the system should provide for participation of all students. Reasonable adaptations and accommodations should be made for students with disabilities and limited English proficient students.

- Assessment results should be reported in aggregate for the full group of test takers, disaggregated for specified population groups, and at the individual level. Reports should include both descriptive and diagnostic information.

Appraisal of Match

- No fundamental incongruity between NCLB and the Commission's 9 Requirements
- Much of what is embedded in the 9 requirements is supportive of the goals of NCLB
- Proof of concept -- is it doable in science and how?

Application of Ideas in Physical Science

- Goal was to see if the Commission "Model" could be instantiated with respect to a significant chunk of the National Science Education Standards
- Given time and money, design team chose to focus on science as inquiry **and** one content area -- physical science
- Team was assisted by a group of scientist-educators and a Dec. meeting in Irvine

Scientist-Educators

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Henry Heikkinen, U. of Northern Colorado

Smith Holt, Oklahoma State U.

John Layman, U. Maryland

A. Truman Schwartz, Macalester College

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Phases of the Discussion & Decision Making

- Starting point -- NSES framework
- Narrowing the scope -- grades 6-9
  - Used NSES grades 5-8 standards
- Discussion of science as inquiry skills
- Separate discussion of the content standards
- Emergence of an organizing framework
  - Skills by Concepts Matrix

Skill by Concept Matrix

Physical Science Concepts

Science-as-Inquiry Skills				

Science-as-Inquiry Skills	Physical Science Concepts			
	Characteristic Physical Properties and Changes	Characteristic Chemical Properties and Changes	Forces and Motion	Forms of Energy and Energy Transfer
Identify questions.	1	2	3	4
Design and conduct a science investigation.	5	6	7	8
Use appropriate tools and techniques to gather, analyze, and interpret data.	9	10	11	12
Develop descriptions, explanations, predictions, and critique models using evidence.	13	14	15	16
Think critically and logically to establish the connection between evidence and explanations.	17	18	19	20

Important Science Skills

- **Identify questions.** *Students are able to ask questions that can be investigated scientifically.*

- **Design and conduct a scientific investigation.** *Students are able to observe and describe phenomena, make hypotheses, and identify and control variables.*

- **Use appropriate tools and techniques to gather, analyze, and interpret data.** *Students are able to select the appropriate apparatus and instruments; measure, calculate, and record in appropriate units; find regularities, patterns, and anomalous data; examine data and determine causal relationships if present; present and interpret data (for example, using graphical methods); and interpolate as well as extrapolate.*

Important Science Skills (cont)

- **Develop descriptions, explanations, predictions, and critique models using evidence.** *Students are able to develop descriptions, explanations, and predictions; and critique predictive (scientific) models and explanatory (educational) models.*

- **Think critically and logically to establish the connection between evidence and explanations.** *Students are able to determine the nature of relationships (that is, direct, inverse, and non-existent); relate evidence to an explanation; and focus on both qualitative and quantitative relationships.*

Science-as-Inquiry Skills	Physical Science Concepts			
	Characteristic Physical Properties and Changes	Characteristic Chemical Properties and Changes	Forces and Motion	Forms of Energy and Energy Transfer
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Important Content

- **Characteristic Physical Properties and Changes**. *A substance has characteristic physical properties (such as density, boiling point, melting point, freezing point, and solubility) which are independent of the amount of the substance sampled.*

- **Characteristic Chemical Properties and Changes**. *A substance has characteristic chemical properties, including reactivity toward other chemical substances to form new substances. The mass and identity of the elements in chemical reactions do not change.*

Important Content (cont)

- **Forces and Motion**. *An object at rest or in uniform motion will remain in that state unless acted on by an outside force. Unbalanced forces will cause changes in the speed and/or direction of an object's motion.*
- **Forms of Energy and Energy Transfer**. *Energy is associated with heat, light, electricity, mechanical motion, sound, and the composition and molecular structure of chemical compounds. Energy can be transformed and transferred. (For example, heat can be transferred by conduction, convection, and radiation, and it always flows from a higher to a lower temperature.) Energy is conserved.*

Science-as-Inquiry Skills	Physical Science Concepts			
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Constraints & Design Decisions

- Assumed a state assessment with 90-100 minutes of total testing time
- Assumed that across Physical-Life-Earth & Space Sciences there might be a total of 12-15 “key” concepts to assess.
- Assumed 15-20 minutes of assessment time to assess mastery of any skill.
- Tradeoff: All concepts on the assessment list but in any given year only 6 are assessed and this varies randomly over years

Recommendations

- **Recommendation 1.** If possible, science tests should be given near the close of *every* grade where meaningful science education is to occur. However, if only one NCLB test per grade-range is to be given, it should be administered one grade *prior* to the end of a NCLB-stipulated grade-range.

- **Recommendation 2.** A state department of education should develop and distribute two or more classroom assessments for each curricular aim eligible to be assessed on the state's annual NCLB science tests.

Recommendations (cont)

- **Recommendation 3.** A large proportion of an NCLB test should be focused on students' concept-mastery rather than their skill-mastery.

- **Recommendation 4.** For economy's sake, the vast majority of an NCLB test's items will be selected-response in nature, but a modest proportion of the test items should require constructed responses.

Recommendations (cont)

- **Recommendation 5.** Provide powerful professional development for the state's science teachers so that they can learn how to derive optimal instructional insights from instructionally supportive NCLB assessments.

- **Recommendation 6.** The state department of education should distribute to each district a set of affective, anonymously completed self-report inventories that teachers can use to gauge their students' science-related attitudes and interests.

Assessment Descriptions & Example Items

- Critical feature of an instructionally supportive accountability test is that it is based on comprehensible assessment descriptions
- Candidate descriptions are included in the report:
  - Characteristic physical properties and changes
  - Forces and motion
- Example items for cells in the matrix are also included

Science-as-Inquiry Skills	Physical Science Concepts			
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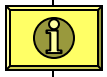
Develop descriptions, explanations, predictions, and critique models using evidence.	13 	14		
Think critically and logically to establish the connection between evidence and explanations.		18	19	20

CHARACTERISTIC PHYSICAL PROPERTIES AND CHANGES

Content. **Students should understand the following scientific *concepts* (for example, mass) and scientific *principles* (for example, ÒMaterials can dissolve in liquids to form solutions.Ó) well enough to respond correctly to previously unencountered test items or tasks calling for the *application* of that scientific content:**

1. **Properties of matter**: A sample of matter can exist as a solid, liquid, or gas, all of which have mass and occupy volume.

    (1) The mass and volume of a sample of matter may be related by its density (d=m/v).
    (2) Density is a characteristic property of a substance, though it varies with temperature.
    (3) Density is independent of the amount of sample.
    (4) In general, solids are more dense than liquids which are more dense than gases.

    (1) **Changes in state**: Transformations can and do occur between physical states.

        a. Mass is conserved during changes of state.
        b. These changes of state are accompanied by the absorption or release of thermal energy (heat).
        c. Boiling point and melting point are characteristic properties of substances.
        d. Melting point and boiling point are independent of the amount of sample.

    (2) **Solutions**: Some materials dissolve in liquids to form solutions.

        a. Mass is conserved when solutions are formed.
        b. Solutions may be separated into components by physical means.
        c. There is a limit to the amount of solid that will dissolve in a given amount of liquid.
        d. The quantity of solid that can dissolve in a liquid is affected by temperature, nature of the liquid, and nature of the solid.

Illustrative Items. The two sample items on the next page might be used, *along with other types of items*, to assess a studentÕs ability to master applications of the above content:

Sample Item 1

A chunk of metal is cut into four pieces of different masses. What is true of the densities of the parts?

* a. The density of each of the parts is the same.
b. The density of the original chunk of metal is equal to the sum of the densities of the four parts.
c. The density of the largest piece of metal is greater than the density of the smallest piece of metal.
d. The density of the piece of metal with the greatest mass is greater than the density of the piece of metal with the smallest mass.

Sample Item 2

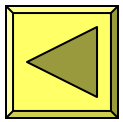
A student collected samples of snow from two locations around her school. She collected the snow by scooping a 250mL beaker in the snow and leveling the top. She did not pack the snow in the beakers. She weighed each of the 250mL-samples of snow. Sample A from the sunny side of the school had a mass of 22.3 g. Sample B from the north side of the school had a mass of 21.4 g. After the snow melted, she measured the volumes of water produced.

(1) How does the volume of water in Sample A compare with the volume of water in Sample B?

[Correct answers should be essentially equivalent or paraphrased versions of the following: The volume of water in Sample A is more than the volume of water in Sample B.]

(2) Explain your answer.

[Correct answers should be essentially equivalent or paraphrased versions of the following: When a sample of a liquid melts, its mass stays the same. The volume of a 22.3-g sample of water is greater than the volume of a 21.4-g water sample.]



FORCES AND MOTION

Content. Students should understand the following *concepts* (for example, acceleration) and *principles* (for example, ÒThe motion of an object under the influence of a constant force increases at a constant rate.Ó) well enough to respond correctly to previously unencountered test items or tasks calling for the *application* of that scientific content:

Motion of Objects

(1) **Uniform motion**: Students demonstrate their understanding of uniform motion by their ability to employ scientific terms related to uniform motion and their ability to:

a. Explain and give examples of how the motion of an object can be described by its position, speed, and direction.
b. Graph and interpret distance and/or position vs. time for uniform motion.

2. **Accelerated motion**: Students demonstrate their understanding of accelerated motion by their ability to define scientific terms related to accelerated motion and their ability to:

a. Explain and give examples of how the motion of an object can be described by its position, velocity (direction of motion and speed), and acceleration.
b. Graph and interpret distance and/or position vs. time graphs and velocity vs. time graphs for constantly accelerated motion.

Forces

1. **Co-linear forces**: Students demonstrate their understanding of co-linear forces by their ability to define scientific terms related to co-linear forces and their ability to:

(1) Describe forces according to their magnitude and direction.
(2) Describe the influence of forces on the motion of an object, indicating that in the case of multiple forces, it is the net force that influences the motion.
(3) Give examples of equal co-linear forces applied in opposite directions to the same object, that is, find the net force on that object.
(4) Describe the influence of one or more forces on the motion of an object, indicating that in the case of multiple forces, it is the net force that influences the motion.
(5) Find the net force on an object subject to two equal and opposite forces.
(6) Explain how an unbalanced (net) force on an object changes the speed or direction of the object's motion.

Illustrative Items. The two sample items on the next page might be used, *along with other types of items*, to measure a studentÕs understanding of the above content:

Sample Item 1

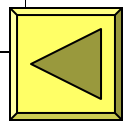
An object is accelerating when

(1) it is not moving at all.
* (2) its direction or speed is changing.
(3) its velocity or speed is constant.
(4) its position is changing at a constant rate.

Sample Item 2

Jill and Jack are having a disagreement. Jill says that when her full bottle of juice is sitting on the table, the table is pushing up on the bottle. Jack says that this is silly. If the table were pushing up on the bottle, the bottle would be moving upward. Who do you think is right, Jill or Jack? Explain your answer and include a diagram that will help clarify your explanation.

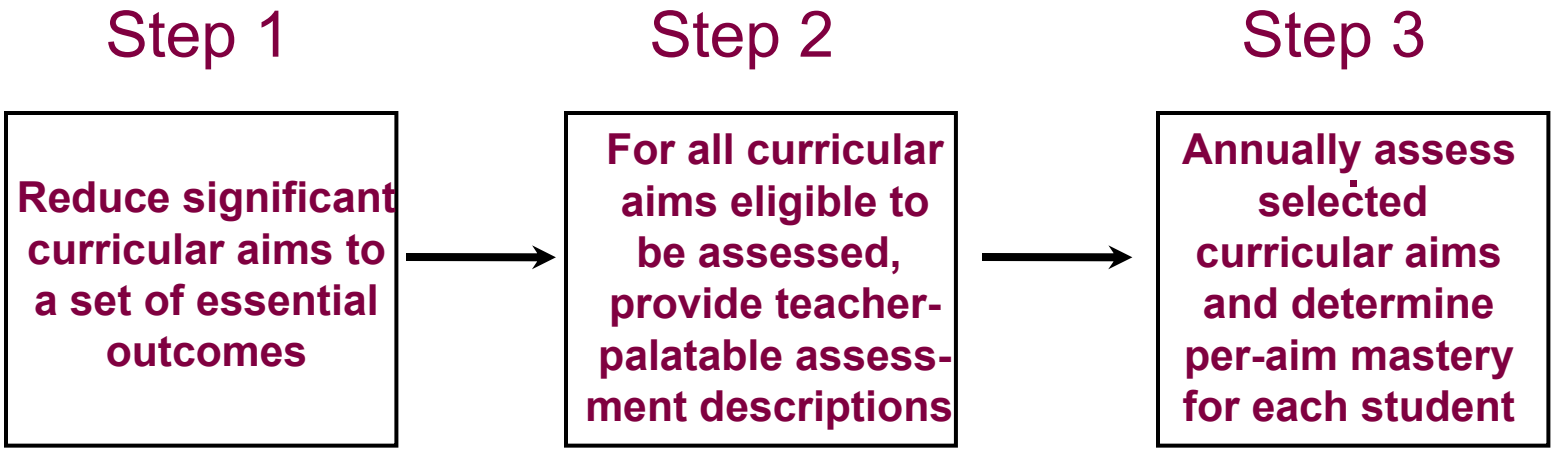
[Correct answers should be essentially equivalent or paraphrased versions of the following: Jill is right. The table is pushing up on the juice bottle. The bottle does not change its motion because gravity is pulling down on the bottle with the same force as the table is pushing up on the bottle. The net force on the bottle is zero, so the bottle is not changing its motion. It is not being accelerated. The diagram should show the juice bottle (or a dot representing the juice bottle) and one arrow pointing up from the bottle representing the upward push of the table on the bottle, as well as an arrow of equal lengthÑ originating from the same spotÑpointing downward, representing the pull of gravity on the bottle.]



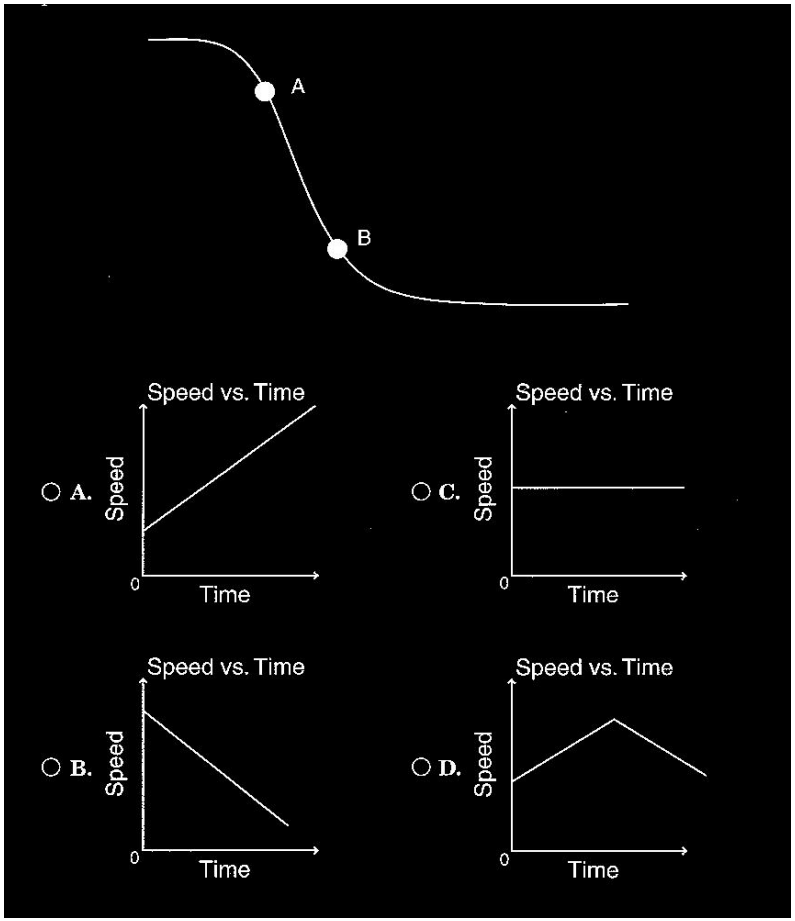
Details of Assessment Development & Implementation

- Report contains a section with illustrative "RFP" language
- RFP lays out specific activities and the rationale for each activity
- RFP lays out products to be generated
  - Multiple components consistent with the overall design recommendations
  - Comprehensive model that includes various checks and balances

Summary of Proposed Process



Cell No. 11:

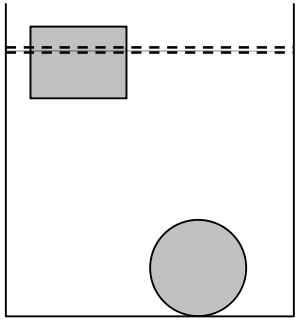


1. Which graph best represents the speed of a roller coaster moving from point A to point B?#

[Correct answer: Graph A]

Cell No. 13:

2. A solid ball and a cube each have a mass of 75 g. Both are placed in a beaker of water and the diagram shows the results. Why does the ball sink and the cube float?



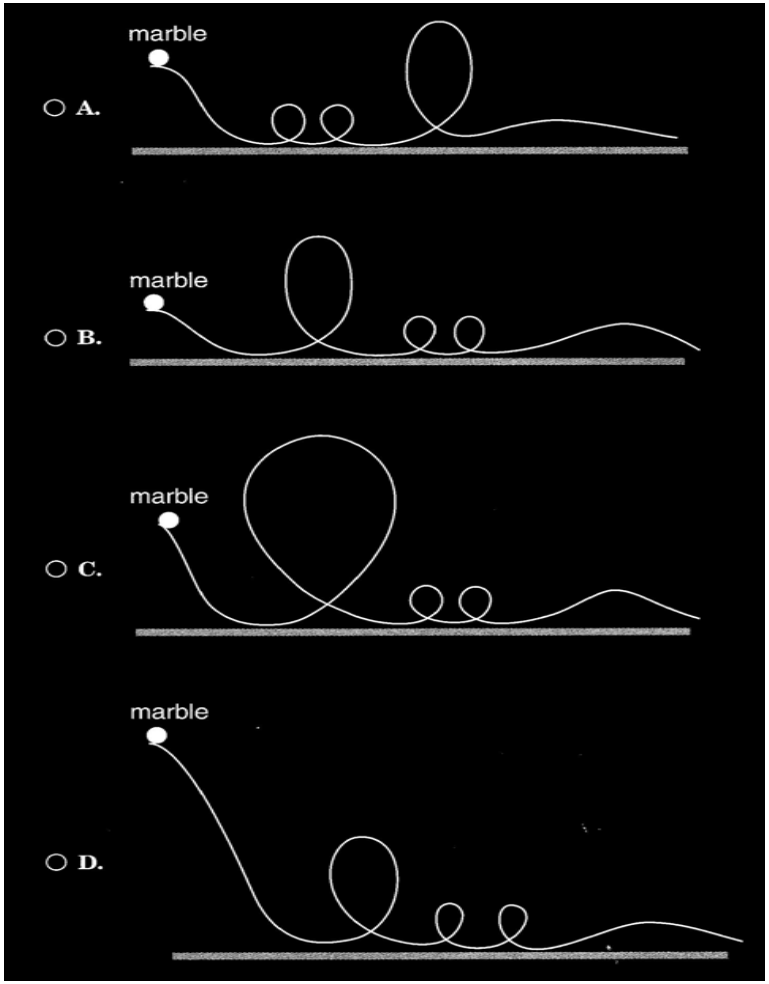
[Correct answers should include the following: (1) the ball has less volume than the cube so it is denser than the cube; (2) the cube has more volume than the ball, so it is less dense than the ball; (3) the cube is less dense than the ball; and (4) density depends upon both mass and volume.]

Cell No. 14:

3. Iron rusting can be explained as a chemical change. What evidence can be used to support this explanation?

[Correct answers should include the following: color change; turns red or orange; and a new substance formed.]

Cell No. 15:



4. Which picture best represents a model that the marble will complete all loops when released?#

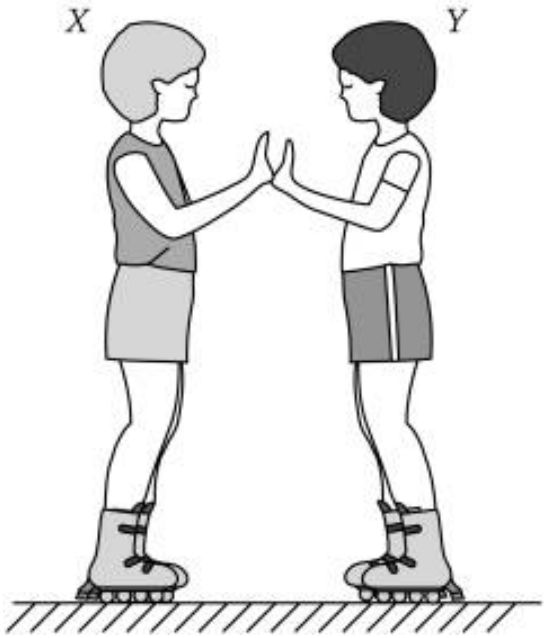
   [Correct answer: Picture D]

5. In which model does the marble have the greatest stored energy?#

   [Correct answer: Picture D]

Cell No. 16:

6. Two boys wearing in-line skates are standing on a smooth surface with the palms of their hands touching and their arms bent as shown above. If Boy X pushes by straightening his arms out while Boy Y holds his arms in the original position, what is the motion of the two boys?#



a. Boy X does not move and Boy Y moves backward.
b. Boy Y does not move and Boy X moves backward.
* c. Boy X and Boy Y both move backward.
d. The motion depends on how hard Boy X pushes.

Cell No. 17:

8. A student decided to determine how sweet she could make a solution of sugar in water. She conducted an investigation by carefully adding sugar, one scoop at a time, to a given volume of water at various temperatures, stirring until the sugar was dissolved. She stopped adding sugar when it no longer dissolved in the water, and then counting the number of scoops of sugar that completely dissolved. During the investigation, she collected the data displayed in the following table.

Beaker	Water Volume, mL	Total Number of Scoops of Sugar that Dissolved	Water Temperature, C
#1	100.0	6	20
#2	100.0	8	30
#3	100.0	9	40
#4	100.0	10	50

(a) What are the controlled variables in this experiment?

[Correct answers should identify (1) volume of water and (2) stirring.]

(1) Draw a graph showing the relationship between the independent and dependent variables in this investigation.

[An appropriate graph must show a direct relationship between the water temperature and the total number of scoops of sugar that dissolve.]

(2) Give an explanation for the observed patterns within the data given above.

[Correct answers should indicate that the total quantity of a solid that can dissolve in a liquid generally increases as the temperature of the liquid increases. At higher temperatures, the liquid is able to keep more sugar in the solution].