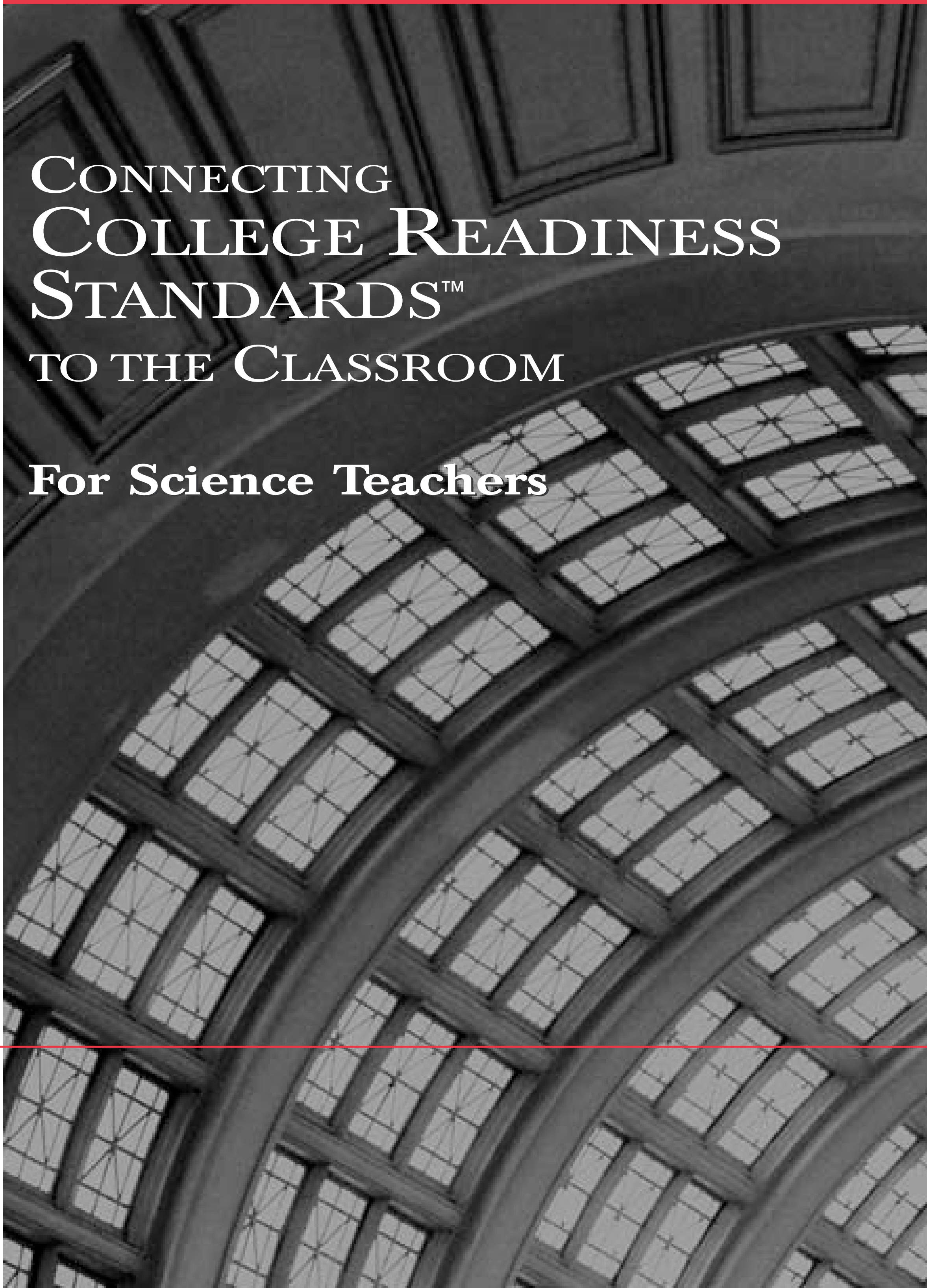
PLAN®



Connecting College Readiness Standards™ to the Classroom

For Science Teachers

ACT®

ACT endorses the *Code of Fair Testing Practices in Education* and the *Code of Professional Responsibilities in Educational Measurement*, guides to the conduct of those involved in educational testing. ACT is committed to ensuring that each of its testing programs upholds the guidelines in each *Code*.

A copy of each *Code* may be obtained free of charge from ACT Customer Services (68), P.O. Box 1008,
Iowa City, IA 52243-1008, 319/337-1429.

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INTRODUCTION

ACT has developed this guide to help classroom teachers, curriculum coordinators, and counselors interpret the College Readiness Standards™ report for PLAN® Science. The guide includes:

- A description of the **College Readiness Standards** for PLAN
- A description of the **PLAN Science Test**
- A set of **sample test questions**
- A description of the **Assessment-Instruction Link**
- A set of classroom **instructional activities**

The College Readiness Standards for PLAN are statements that describe what students who score in the five score ranges 13–15, 16–19, 20–23, 24–27, and 28–32 are *likely* to know and to be able to do. The statements are generalizations based on the performance of many students scoring in these five score ranges. College Readiness Standards have not been developed for students whose scores fall in the 1–12 range because these students, as a group, do not demonstrate skills similar to each other consistently enough to permit useful generalizations.

The College Readiness Standards for PLAN are accompanied by ideas for progress that help teachers identify ways of enhancing student learning based on the scores students receive.

The College Readiness Standards Information Services provide five aggregate reports for PLAN. Four of these reports are content specific: each presents the scores of your students in each of the four content areas the PLAN test measures—English, Mathematics, Reading, and Science. These four content-specific reports present PLAN results using ACT's College Readiness Standards. The fifth report, the Summary Profile, summarizes the scores of your students across all four content areas. All five reports provide data that compare the performance of your students (Local) with all students in a nationally representative comparison group (norm group) and with a subgroup of those students who have indicated that they plan to attend college.

PLAN is a curriculum-based assessment program developed by ACT to help tenth graders plan their academic careers and prepare for entry into college or the world of work. As part of ACT's Educational Planning and Assessment System (EPAS™), PLAN is complemented by EXPLORE®, ACT's eighth- and ninth-grade program, and by the ACT®, for eleventh and twelfth graders. We hope this guide helps you assist your students as they plan and pursue their future studies.

"The role of standardized testing is to let parents, students, and institutions know what students are ready to learn next."

— Ralph Tyler, October 1991
Chairman Emeritus of
ACT's Board of Trustees

The College Readiness Standards Report for PLAN Science

The College Readiness Standards report for PLAN Science allows you to compare the performance of students in your school with the performance of students nationwide. The report provides summary information you can use to map the development of your students' knowledge and skills in science. Used along with your own classroom observations and with other resources, the test results can help you to analyze your students' progress in science and to identify areas of strength and areas that need more attention. You can then use the Standards as one source of information in the instructional planning process.

A sample report appears on the next page. An explanation of its features is provided below.

A This section briefly explains the uses of the report to help you interpret the test results.

B These are the six score ranges reported for the College Readiness Standards for PLAN. To determine the number of score ranges and the width of each score range, ACT staff reviewed normative data, college admission criteria, and information obtained through ACT's Course Placement Service. For a more detailed explanation of the way the score ranges were determined, see page 5.

C This section compares the percent of students who scored in a particular score range at an individual school (Local) with the percent of all tenth-grade students in the norm group and with a subgroup of college-bound tenth-grade students who scored in the same range. The percent of students for the norm group and subgroup is based on the most current set of nationally representative norms. The number of local school students who scored in each of the six score ranges is provided in the column to the left of each bar graph; the total number of tenth-grade students tested locally is provided at the top of the report.

D The College Readiness Standards were developed by identifying the knowledge and skills students need in order to respond successfully to questions on the PLAN Science Test. As you review the report for PLAN Science, you will note that the Standards are cumulative, which means that if students score, for example, in the 20–23 score range, they are likely to be able to demonstrate most or all of the knowledge and skills in the 13–15, 16–19, and 20–23 score ranges. Students may be able to demonstrate some of the skills in the next score range, 24–27, but not consistently enough as a group to reach that score range. A description of the way the College Readiness Standards were developed can be found on pages 5–6.

E The "ideas for progress" are statements that provide suggestions for learning experiences that students might benefit from. These ideas for progress are arranged by score range and strand. Although many of the ideas cross more than one strand, a primary strand has been identified for each in order to facilitate their use in the classroom. Ideas for progress are provided for the 28–32 score range, the highest score range for PLAN. The ideas for the 28–32 score range are shown to suggest educational experiences from which students may benefit before they take the ACT.

F Page 2 of the report profiles the test results, College Readiness Standards, and ideas for progress for score range 28–32.

G The Science College Readiness Standards are measured in the context of science topics students encounter in science courses. This section of the report lists representative topics. These topics can be found on page 8.

College Readiness Standards
Information Services

PLAN® Science Report

The College Readiness Standards report for PLAN Science allows you to compare the performance of students in your school with the performance of students nationwide. For an explanation of the report's features, see page 2 in the Science guide *Connecting College Readiness Standards to the Classroom.* A

Sample School (000000)
Standard Report
Any Town, US

Number of Students: 282
Grade: 10
2005-2006 Academic Year

Score Range	No. of Students	Percentage: Local	Percentage: College-Bound	Percentage: National		Interpretation of Data	Scientific Investigation	Evaluation of Models, Inferences, and Experimental Results
1–12	1	0%	2%	2%	Standards	■ Students who score in the 1–12 range are most likely beginning to develop the knowledge and skills assessed in the other score ranges.		
					Ideas for progressing to 13–15 score range	■ locate data in simple tables and graphs ■ become familiar with different types of graphs (e.g., line graphs, pie charts, bar graphs) ■ become familiar with units of measurement commonly used in science	■ observe experiments being performed and discuss what was done and why	■ discuss what hypotheses and conclusions are and how they are different from each other
13–15	18	6%	27%	20%	Standards	■ Select a single piece of data (numerical or nonnumerical) from a simple data presentation (e.g., a table or graph with two or three variables; a food web diagram) ■ Identify basic features of a table, graph, or diagram (e.g., headings, units of measurement, axis labels)		
					Ideas for progressing to 16–19 score range	■ locate several data points in a simple table or graph and make comparisons between them ■ become familiar with common terms used in science (e.g., *star, force, mineral*) ■ create basic tables and graphs from sets of scientific data ■ read newspaper and magazine articles pertaining to science and technology and discuss main points with peers ■ describe trends and relationships in data displayed in simple tables and graphs	■ determine an appropriate method for performing a simple experiment ■ perform simple laboratory activities designed to teach familiarity with a number of commonly used tools (e.g., thermometers, balances, glassware)	■ read science articles of an appropriate level from newspapers and science newsmagazines and identify any hypotheses or conclusions made by the author(s) E
16–19 B	80	28% C	49%	51%	Standards	■ Select two or more pieces of data from a simple data presentation ■ Understand basic scientific terminology ■ Find basic information in a brief body of text ■ Determine how the value of one variable changes as the value of another variable changes in a simple data presentation	D ■ Understand the methods and tools used in a simple experiment	
					Ideas for progressing to 20–23 score range	■ display data gathered in laboratory exercises in a variety of formats (e.g., line graphs, pie charts, bar graphs)	■ perform experiments that require more than one step ■ conduct a simple experiment that makes use of a control group	■ read descriptions of actual experiments (e.g., completed science fair research, simple experiments from science education journals) and discuss whether the conclusions that were made support or contradict the hypotheses ■ formulate hypotheses, predictions, or conclusions based on the results of an experiment
20–23	141	50%	19%	23%	Standards	■ Select data from a complex data presentation (e.g., a table or graph with more than three variables; a phase diagram) ■ Compare or combine data from a simple data presentation (e.g., order or sum data from a table) ■ Translate information into a table, graph, or diagram	■ Understand the methods and tools used in a moderately complex experiment ■ Understand a simple experimental design ■ Identify a control in an experiment ■ Identify similarities and differences between experiments	■ Select a simple hypothesis, prediction, or conclusion that is supported by a data presentation or a model ■ Identify key issues or assumptions in a model
					Ideas for progressing to 24–27 score range	■ examine line graphs to determine if they show a direct or inverse relationship between variables ■ become familiar with scatterplots ■ determine a simple mathematical relationship between two variables ■ integrate scientific information from popular sources (e.g., newspapers, magazines, the Internet) with that found in textbooks	■ perform several repetitions of an experiment to determine the reliability of results	■ evaluate whether the data produced by an experiment adequately support a given conclusion ■ compare and contrast two different models about a scientific phenomenon
24–27	27	10%	2%	3%	Standards	■ Compare or combine data from two or more simple data presentations (e.g., categorize data from a table using a scale from another table) ■ Compare or combine data from a complex data presentation ■ Interpolate between data points in a table or graph ■ Determine how the value of one variable changes as the value of another variable changes in a complex data presentation ■ Identify and/or use a simple (e.g., linear) mathematical relationship between data ■ Analyze given information when presented with new, simple information	■ Understand the methods and tools used in a complex experiment ■ Understand a complex experimental design ■ Predict the results of an additional trial or measurement in an experiment ■ Determine the experimental conditions that would produce specified results	■ Select a simple hypothesis, prediction, or conclusion that is supported by two or more data presentations or models ■ Determine whether given information supports or contradicts a simple hypothesis or conclusion, and why ■ Identify strengths and weaknesses in one or more models ■ Identify similarities and differences between models ■ Determine which model(s) is(are) supported or weakened by new information ■ Select a data presentation or a model that supports or contradicts a hypothesis, prediction, or conclusion
					Ideas for progressing to 28–32 score range	■ relate scientific information contained in written text to numerical data ■ manipulate algebraic equations that represent data	■ determine the hypothesis behind an experiment that requires more than one step ■ determine alternate methods of testing a hypothesis	■ communicate findings of an experiment and compare conclusions with those of peers

continued

Score Range	No. of Students	Percentage: Local	Percentage: College-Bound	Percentage: National		Interpretation of Data	Scientific Investigation	Evaluation of Models, Inferences, and Experimental Results
28–32	15	5% F	1%	1%	Standards	■ Compare or combine data from a simple data presentation with data from a complex data presentation ■ Identify and/or use a complex (e.g., nonlinear) mathematical relationship between data ■ Extrapolate from data points in a table or graph	■ Determine the hypothesis for an experiment ■ Identify an alternate method for testing a hypothesis	■ Select a complex hypothesis, prediction, or conclusion that is supported by a data presentation or model ■ Determine whether new information supports or weakens a model, and why ■ Use new information to make a prediction based on a model
					Ideas for progressing to 33–36 score range (ACT)	■ examine two or more related sets of data and then combine those data in ways that are useful	■ carry out scientific investigations in which the importance of accuracy and precision is stressed ■ consider how changing an experimental procedure will affect the results of their scientific investigations ■ design and carry out additional scientific inquiries to answer specific questions	■ formulate hypotheses, predictions, or conclusions by comparing and contrasting several different sets of data from different experiments ■ evaluate the merits of a conclusion based on the analysis of several sets of data ■ seek out new information that enhances or challenges their existing knowledge

Science College Readiness Standards are measured in the context of science topics students encounter in science courses. These topics may include:

Life Science/Biology	Physical Science/Chemistry, Physics	Earth & Space Science
• Animal behavior	• Atomic structure	• Earthquakes and volcanoes
• Animal development and growth	• Chemical bonding, equations, nomenclature, reactions	• Earth's atmosphere
• Body systems	• Electrical circuits	• Earth's resources
• Cell structure and processes	• Elements, compounds, mixtures	• Fossils and geological time
• Ecology	• Force and motions	• Geochemical cycles
• Evolution	• Gravitation	• Groundwater
• Genetics	• Heat and work	• Lakes, rivers, oceans
• Homeostasis	• Kinetic and potential energy	• Mass movements
• Life cycles	• Magnetism	• Plate tectonics
• Molecular basis of heredity	• Momentum	• Rocks, minerals
• Origin of life	• The Periodic Table	• Solar system
• Photosynthesis	• Properties of solutions	• Stars, galaxies, and the universe
• Plant development, growth, structure	• Sound and light	• Water cycle
• Populations	• States, classes, and properties of matter	• Weather and climate
• Taxonomy	• Waves	• Weathering and erosion

G

Description of the College Readiness Standards

What Are the College Readiness Standards?

The College Readiness Standards communicate educational expectations. Each Standard describes what students who score in the designated range are *likely* to be able to do with what they know. Students can typically demonstrate the skills and knowledge within the score ranges preceding the range in which they scored, so the College Readiness Standards are cumulative.

In helping students make the transition from high school to postsecondary education or to the world of work, teachers, counselors, and parents can use the College Readiness Standards for PLAN to interpret students' scores and to understand which skills students need to develop to be better prepared for the future.

How Were the Score Ranges Determined?

To determine the number of score ranges and the width of each score range for PLAN, ACT staff reviewed PLAN normative data and considered the relationship among EXPLORE, PLAN, and the ACT.

In reviewing the PLAN normative data, ACT staff analyzed the distribution of student scores across the score scale. Because PLAN and the ACT have a common score scale, ACT can provide PLAN examinees with an estimated ACT Composite score. When the score ranges were being determined, therefore, both the PLAN score scale, 1–32, and the ACT score scale, 1–36, were reviewed side by side. And because many students take PLAN to determine how well they might perform on the ACT, the course-placement research that ACT has conducted over the last forty years was also reviewed. ACT's Course Placement Service provides colleges and universities with cutoff scores that are used to place students into appropriate entry-level courses in college; and these cutoff scores were used to help define the score ranges.

After analyzing all the data and reviewing different possible score ranges, ACT staff concluded that using the six score ranges 1–12, 13–15, 16–19, 20–23, 24–27, and 28–32 would best distinguish students' levels of achievement so as to assist teachers, administrators, and others in relating PLAN test scores to students' attainment of specific skills and understandings.

How Were the College Readiness Standards Developed?

After reviewing normative data, college admission criteria, and information obtained through ACT's Course Placement Service, content experts wrote the College Readiness Standards based on their analysis of the skills and knowledge students need in order to successfully respond to the test questions in each score range. Experts analyzed numerous test questions that had been answered correctly by 80%

> **"The examination should describe the student in meaningful terms–meaningful to the student, the parent, and the elementary and high school teacher–meaningful in the sense that the profile scores correspond to recognizable school activities, and directly suggest appropriate distributions of emphasis in learning and teaching."**
>
> — E. F. Lindquist, February 1958
> Cofounder of ACT

or more of the examinees within each score range. The 80% criterion was chosen because it offers those who use the College Readiness Standards a high degree of confidence that students scoring in a given score range will most *likely* be able to demonstrate the skills and knowledge described in that range.

As a content validity check, ACT invited nationally recognized scholars from high school and university Science and Science Education departments to review the College Readiness Standards for the PLAN Science Test. These teachers and researchers provided ACT with independent, authoritative reviews of the ways the College Readiness Standards reflect the skills and knowledge students need to successfully respond to the questions on the PLAN Science Test.

Because PLAN is curriculum based, ACT and independent consultants conduct a review every three to four years to ensure that the knowledge and skills described in the Standards and outlined in the test specifications continue to reflect those being taught in classrooms nationwide.

How Should the College Readiness Standards Be Interpreted and Used?

The College Readiness Standards reflect the progression and complexity of the skills measured in PLAN. Because no PLAN test form measures all of the skills and knowledge included in the College Readiness Standards, the Standards must be interpreted as skills and knowledge that *most* students who score in a particular score range are *likely* to be able to demonstrate. Since there were relatively few test questions that were answered correctly by 80% or more of the students who scored in the lower score ranges, the Standards in these ranges should be interpreted cautiously. The skills and understandings of students who score in the 1–12 score range may still be evolving. For these students the skills and understandings in the higher score ranges could become their target achievement outcomes.

It is important to recognize that PLAN does not measure everything students have learned nor does any test measure everything necessary for students to know to be successful in college or in the world of work. The PLAN Science Test includes questions from a large domain of skills and from areas of knowledge that have been judged important for success in college and beyond. Thus, the College Readiness Standards should be interpreted in a responsible way that will help students understand what they need to know and do if they are going to make a successful transition to college, vocational school, or the world of work. As students choose courses they plan to take in high school, they can use the Standards to identify the skills and knowledge they need to develop to be better prepared for their future. Teachers and curriculum coordinators can use the Standards to learn more about their students' academic strengths and weaknesses and can then modify their instruction and guide students accordingly.

How Are the College Readiness Standards Organized?

As content experts reviewed the test questions connected to each score range, distinct yet overlapping areas of knowledge and skill were identified. For example, there are many types of questions in which students are asked to demonstrate that they understand the components of a scientific investigation. Therefore, *Scientific Investigation* is one area, or *strand,* within the College Readiness Standards for PLAN Science. The other two strands are *Interpretation of Data* and *Evaluation of Models, Inferences, and Experimental Results.*

The strands provide an organizational framework for the College Readiness Standards statements. As you review the Standards, you will note a progression in complexity within each strand. For example, in the 13–15 range for the Interpretation of Data strand, students are able to "select a single piece of data (numerical or nonnumerical) from a simple data presentation (e.g., a table or graph with two or three variables; a food web diagram)," while in the 28–32 range students demonstrate that they are able to "compare or combine data from a simple data presentation with data from a complex data presentation."

The Standards are complemented by brief descriptions of learning experiences from which high school students might benefit. Based on the College Readiness Standards, these ideas for progress are designed to provide classroom teachers with help for lesson plan development. These ideas, which are given in Table 1, demonstrate one way that information learned from standardized test results can be used to inform classroom instruction.

Because students learn over time and in various contexts, it is important to use a variety of instructional methods and materials to meet students' diverse needs and to help strengthen and build upon their knowledge and skills. The ideas for progress offer teachers a variety of suggestions to foster learning experiences from which students would likely benefit as they move from one level of learning to the next.

Because learning is a complex and individual process, it is especially important to use multiple sources of information—classroom observations and teacher-developed assessment tools, as well as standardized tests—to accurately reflect what each student knows and can do. The Standards and ideas for progress, used in conjunction with classroom-based and curricular resources, help teachers and administrators to guide the whole education of every student.

What Are the PLAN Science Test College Readiness Standards?

Table 1 on pages 8–10 suggests links between what students are *likely* to be able to do (the College Readiness Standards) and what learning experiences students would likely benefit from.

The College Readiness Standards are organized both by score range (along the left-hand side) and by strand (across the top). The lack of a College Readiness Standards statement in a score range indicates that there was insufficient evidence with which to determine a descriptor.

The ideas for progress are also arranged by score range and by strand. Although many of the ideas cross more than one strand, a primary strand has been identified for each in order to facilitate their use in the classroom. For example, the statement in the 20–23 score range "evaluate whether the data produced by an experiment adequately support a given conclusion" brings together concepts from all three strands: Interpretation of Data; Scientific Investigation; and Evaluation of Models, Inferences, and Experimental Results. However, this idea is primarily linked to the Evaluation of Models, Inferences, and Experimental Results strand.

As you review the table, you will note that in the Scientific Investigation strand and the Evaluation of Models, Inferences, and Experimental Results strand, ideas for progress based on the knowledge and skills being tested are provided even where there are no Standards in the next higher range. Ideas for progress have been provided for the 28–32 score range, which is the highest score range for PLAN. PLAN is designed to measure knowledge and skills achieved through the tenth grade. Ideas for progress for the 28–32 score range are shown to suggest educational experiences from which students may benefit before they take the ACT.

PLAN SCIENCE TEST

Table 1: The College Readiness Standards

The Standards describe what students who score in the specified score ranges are *likely* to know and to be able to do. The ideas for progress help teachers identify ways of enhancing students' learning based on the scores students receive.

Score Range		*Interpretation of Data*	*Scientific Investigation*	*Evaluation of Models, Inferences, and Experimental Results*
1–12	**Standards**	■ Students who score in the 1–12 range are most likely beginning to develop the knowledge and skills assessed in the other score ranges.		
	ideas for progress	■ locate data in simple tables and graphs ■ become familiar with different types of graphs (e.g., line graphs, pie charts, bar graphs) ■ become familiar with units of measurement commonly used in science	■ observe experiments being performed and discuss what was done and why	■ discuss what hypotheses and conclusions are and how they are different from each other
13–15	**Standards**	■ Select a single piece of data (numerical or nonnumerical) from a simple data presentation (e.g., a table or graph with two or three variables; a food web diagram) ■ Identify basic features of a table, graph, or diagram (e.g., headings, units of measurement, axis labels)		
	ideas for progress	■ locate several data points in a simple table or graph and make comparisons between them ■ become familiar with common terms used in science (e.g., *star, force, mineral*) ■ create basic tables and graphs from sets of scientific data ■ read newspaper and magazine articles pertaining to science and technology and discuss main points with peers ■ describe trends and relationships in data displayed in simple tables and graphs	■ determine an appropriate method for performing a simple experiment ■ perform simple laboratory activities designed to teach familiarity with a number of commonly used tools (e.g., thermometers, balances, glassware)	■ read science articles of an appropriate level from newspapers and science newsmagazines and identify any hypotheses or conclusions made by the author(s)

Science College Readiness Standards are measured in the context of science topics students encounter in science courses. These topics may include:

Life Science/Biology	Physical Science/Chemistry, Physics	Earth & Space Science
• Animal behavior • Animal development and growth • Body systems • Cell structure and processes • Ecology • Evolution • Genetics • Homeostasis • Life cycles • Molecular basis of heredity • Origin of life • Photosynthesis • Plant development, growth, structure • Populations • Taxonomy	• Atomic structure • Chemical bonding, equations, nomenclature, reactions • Electrical circuits • Elements, compounds, mixtures • Force and motions • Gravitation • Heat and work • Kinetic and potential energy • Magnetism • Momentum • The Periodic Table • Properties of solutions • Sound and light • States, classes, and properties of matter • Waves	• Earthquakes and volcanoes • Earth's atmosphere • Earth's resources • Fossils and geological time • Geochemical cycles • Groundwater • Lakes, rivers, oceans • Mass movements • Plate tectonics • Rocks, minerals • Solar system • Stars, galaxies, and the universe • Water cycle • Weather and climate • Weathering and erosion

PLAN SCIENCE TEST

Table 1: (continued) The College Readiness Standards

The Standards describe what students who score in the specified score ranges are *likely* to know and to be able to do. The ideas for progress help teachers identify ways of enhancing students' learning based on the scores students receive.

Score range		*Interpretation of Data*	*Scientific Investigation*	*Evaluation of Models, Inferences, and Experimental Results*
16–19	**Standards**	■ Select two or more pieces of data from a simple data presentation ■ Understand basic scientific terminology ■ Find basic information in a brief body of text ■ Determine how the value of one variable changes as the value of another variable changes in a simple data presentation	■ Understand the methods and tools used in a simple experiment	
	ideas for progress	■ display data gathered in laboratory exercises in a variety of formats (e.g., line graphs, pie charts, bar graphs)	■ perform experiments that require more than one step ■ conduct a simple experiment that makes use of a control group	■ read descriptions of actual experiments (e.g., completed science fair research, simple experiments from science education journals) and discuss whether the conclusions that were made support or contradict the hypotheses ■ formulate hypotheses, predictions, or conclusions based on the results of an experiment
20–23	**Standards**	■ Select data from a complex data presentation (e.g., a table or graph with more than three variables; a phase diagram) ■ Compare or combine data from a simple data presentation (e.g., order or sum data from a table) ■ Translate information into a table, graph, or diagram	■ Understand the methods and tools used in a moderately complex experiment ■ Understand a simple experimental design ■ Identify a control in an experiment ■ Identify similarities and differences between experiments	■ Select a simple hypothesis, prediction, or conclusion that is supported by a data presentation or a model ■ Identify key issues or assumptions in a model
	ideas for progress	■ examine line graphs to determine if they show a direct or inverse relationship between variables ■ become familiar with scatterplots ■ determine a simple mathematical relationship between two variables ■ integrate scientific information from popular sources (e.g., newspapers, magazines, the Internet) with that found in textbooks	■ perform several repetitions of an experiment to determine the reliability of results	■ evaluate whether the data produced by an experiment adequately support a given conclusion ■ compare and contrast two different models about a scientific phenomenon

PLAN SCIENCE TEST

Table 1: (continued) The College Readiness Standards

The Standards describe what students who score in the specified score ranges are *likely* to know and to be able to do. The ideas for progress help teachers identify ways of enhancing students' learning based on the scores students receive.

		Interpretation of Data	*Scientific Investigation*	*Evaluation of Models, Inferences, and Experimental Results*
24–27	**Standards**	■ Compare or combine data from two or more simple data presentations (e.g., categorize data from a table using a scale from another table) ■ Compare or combine data from a complex data presentation ■ Interpolate between data points in a table or graph ■ Determine how the value of one variable changes as the value of another variable changes in a complex data presentation ■ Identify and/or use a simple (e.g., linear) mathematical relationship between data ■ Analyze given information when presented with new, simple information	■ Understand the methods and tools used in a complex experiment ■ Understand a complex experimental design ■ Predict the results of an additional trial or measurement in an experiment ■ Determine the experimental conditions that would produce specified results	■ Select a simple hypothesis, prediction, or conclusion that is supported by two or more data presentations or models ■ Determine whether given information supports or contradicts a simple hypothesis or conclusion, and why ■ Identify strengths and weaknesses in one or more models ■ Identify similarities and differences between models ■ Determine which model(s) is(are) supported or weakened by new information ■ Select a data presentation or a model that supports or contradicts a hypothesis, prediction, or conclusion
	ideas for progress	■ relate scientific information contained in written text to numerical data ■ manipulate algebraic equations that represent data	■ determine the hypothesis behind an experiment that requires more than one step ■ determine alternate methods of testing a hypothesis	■ communicate findings of an experiment and compare conclusions with those of peers
28–32	**Standards**	■ Compare or combine data from a simple data presentation with data from a complex data presentation ■ Identify and/or use a complex (e.g., nonlinear) mathematical relationship between data ■ Extrapolate from data points in a table or graph	■ Determine the hypothesis for an experiment ■ Identify an alternate method for testing a hypothesis	■ Select a complex hypothesis, prediction, or conclusion that is supported by a data presentation or model ■ Determine whether new information supports or weakens a model, and why ■ Use new information to make a prediction based on a model
	ideas for progress	■ examine two or more related sets of data and then combine those data in ways that are useful	■ carry out scientific investigations in which the importance of accuracy and precision is stressed ■ consider how changing an experimental procedure will affect the results of their scientific investigations ■ design and carry out additional scientific inquiries to answer specific questions	■ formulate hypotheses, predictions, or conclusions by comparing and contrasting several different sets of data from different experiments ■ evaluate the merits of a conclusion based on the analysis of several sets of data ■ seek out new information that enhances or challenges their existing knowledge

Description of the PLAN Science Test

What Does the PLAN Science Test Measure?

The PLAN Science Test is a 30-question, 25-minute test designed to assess the knowledge and the thinking skills, processes, and strategies students acquire in first-year and second-year high school science courses. These skills include analyzing and interpreting data, comparing experimental designs and methods, comparing assumptions underlying experiments, making generalizations, and identifying and evaluating conflicting points of view. The test presents five sets of scientific information, each followed by a number of multiple-choice test questions. The scientific information is conveyed in one of three different formats:

Data Representation. This format, which accounts for 33% of the test, presents students with graphic and tabular materials similar to those found in science journals and texts. The test questions associated with this format measure skills such as graph reading, interpretation of scatterplots, and interpretation of information presented in tables.

Research Summaries. This format, which accounts for 47% of the test, provides students with descriptions of one or more experiments. The test questions focus upon the design of experiments and the interpretation of experimental results.

Conflicting Viewpoints. This format, which accounts for 20% of the test, presents students with expressions of hypotheses, models, or views that, being based on differing premises or on incomplete data, are inconsistent with one another. The test questions focus upon the understanding, analysis, comparison, and evaluation of the alternative viewpoints.

The PLAN Science Test is based upon the type of content that is typically covered in high school general science courses. Materials are drawn from biology, chemistry, Earth/space science, and physics. Each test activity uses stimulus materials from one of these areas. Materials are produced specifically for the Science Test to match the level of complexity of those used in the classroom. The intent is to present students with a situation to engage their reasoning skills, rather than to invite their recall of a classroom activity. Some of the topics included in each content area are summarized below.

Biology. The stimulus materials and questions in this content area cover such topics as cell biology, botany, zoology, microbiology, ecology, genetics, and evolution.

Chemistry. The stimulus materials and questions in this content area cover such topics as atomic theory, inorganic chemical reactions, chemical bonding, reaction rates, solutions, equilibriums, gas laws, electrochemistry, and properties and states of matter.

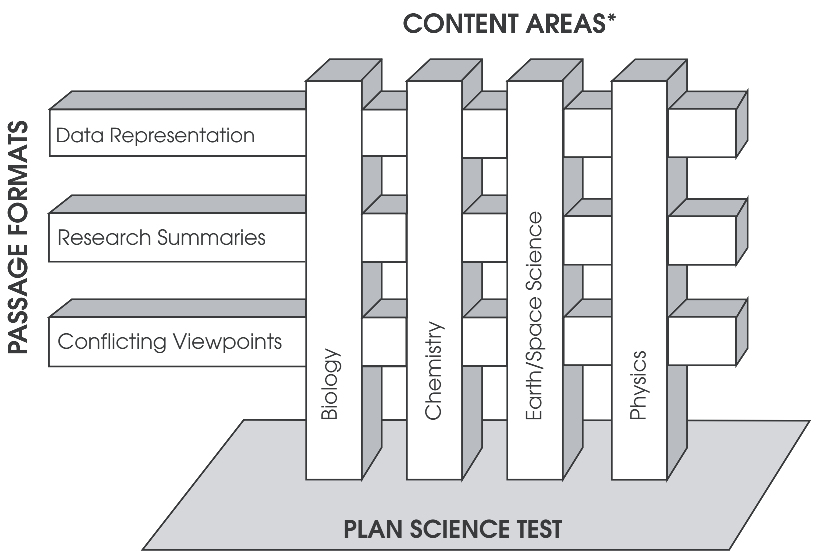
Earth/Space Science. The stimulus materials and questions in this content area cover such topics as geology, meteorology, astronomy, environmental science, and oceanography.

Physics. The stimulus materials and questions in this content area cover such topics as mechanics, energy, thermodynamics, electromagnetism, fluids, solids, and light waves.

Figure 1 on page 12 provides an overview of the structure of the PLAN Science Test.

> **"The test should measure what students can do with what they have learned."**
>
> — (ACT, 1996b, p.1)

The questions in the Science Test are classified according to three primary cognitive levels: understanding, analysis, and generalization. *Understanding* questions test students' ability to comprehend the information presented and, to a limited extent, their understanding of how it fits into the general scheme of the particular stimulus format. *Analysis* questions go beyond the level of understanding questions by testing students' ability to relate a number of components of the presented material to each other on a higher, more abstract level. *Generalization* questions test students' ability to think beyond the presented materials and to see how the stimulus material relates to the rest of the world.



*All four content areas are represented in the test. The content areas are distributed over the differrent formats in such a way that at least one set of scientific information, and no more than two sets, represents each content area.

Adapted from *Mathematics Framework for the 1996 National Assessment of Educational Progress* (p.11)

Figure 1: **PLAN Science Test Content Areas and Passage Formats**

THE NEED FOR THINKING SKILLS

Every student comes to school with the ability to think, but to achieve their goals students need to develop skills such as learning to make new connections between texts and ideas, to understand increasingly complex concepts, and to think through their assumptions. Because of technological advances and the fast pace of our society, it is increasingly important that students not only know information but also know how to critique and manage that information. Students must be provided with the tools for ongoing learning; understanding, analysis, and generalization skills must be developed so that the learner is able to adapt to a variety of situations.

HOW ARE PLAN TEST QUESTIONS LINKED TO THINKING SKILLS?

Our belief in the importance of developing thinking skills in learners was a key factor in the development of PLAN. ACT believes that students' preparation for further learning is best assessed by measuring, as directly as possible, the academic skills that students have acquired and that they will need to perform at the next level of learning. The required academic skills can most directly be assessed by reproducing as faithfully as possible the complexity of the students' schoolwork. Therefore, the PLAN test questions are designed to determine how skillfully students solve problems, grasp implied meanings, draw inferences, evaluate ideas, and make judgments in subject-matter areas important to success in intellectual work both inside and outside school.

Table 2 on pages 14–20 provides sample test questions, organized by score range, that are linked to specific skills within each of the three Science strands. It is important to note the increasing level of science reasoning skills that students scoring in the higher score ranges are able to demonstrate. The questions were chosen to illustrate the variety of content as well as the range of complexity within each strand. The sample test questions for the 13–15, 16–19, 20–23, 24–27, and 28–32 score ranges are examples of items answered correctly by 80% or more of the PLAN examinees who obtained scores in each of these five score ranges.

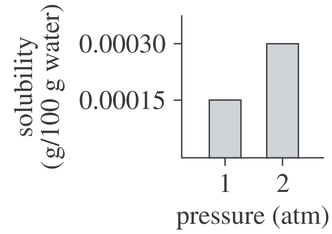
As you review the sample test questions, you will note that each correct answer is marked with an asterisk. Also note that each sample test question includes the passage content area (biology, chemistry, Earth/space science, or physics) and format (data representation, research summaries, or conflicting viewpoints) for the corresponding passage as well as the page number where the passage is located in the appendix.

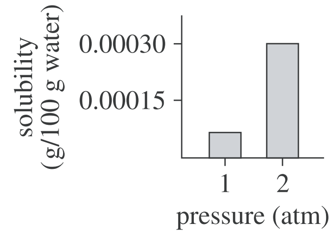
> **"Learning is not attained by chance, it must be sought for with ardour and attended to with diligence."**
>
> — Abigail Adams in a letter to John Quincy Adams

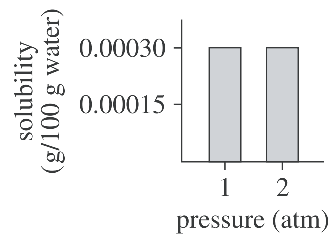
Table 2: **PLAN Sample Test Questions by Score Range**
Interpretation of Data Strand

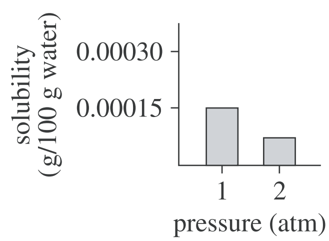
Score Range	Interpretation of Data	Sample Test Questions	Passage Information
13–15	Select a single piece of data (numerical or nonnumerical) from a simple data presentation (e.g., a table or graph with two or three variables; a food web diagram)	According to Study 2, the average Pb concentration in the stream water samples taken at 700 m elevation was closest to which of the following? **A.** 0.020 ppb **B.** 0.035 ppb *__C.__ 0.045 ppb **D.** 0.060 ppb	page 64 Earth/Space Science Research Summaries
	Identify basic features of a table, graph, or diagram (e.g., headings, units of measurement, axis labels)	Which of the following is represented on the vertical axis of Figure 1 ? **A.** Year *__B.__ Average number of visible sunspots **C.** Average number of solar flares **D.** Sunspot diameter	page 66 Earth/Space Science Data Representation
16–19	Find basic information in a brief body of text	According to Experiment 3, what is the relationship between a ball's temperature and the ball's COR ? *__A.__ As the temperature of a ball increases, the COR of the ball increases. **B.** As the temperature of a ball increases, the COR of the ball stays the same. **C.** As the temperature of a ball decreases, the COR of the ball increases. **D.** As the temperature of a ball decreases, the COR of the ball stays the same.	page 68 Physics Research Summaries
	Determine how the value of one variable changes as the value of another variable changes in a simple data presentation	According to the results of Study 2, as elevation decreased from 600 m to 400 m, the Pb concentration of the stream water samples: *__A.__ decreased only. **B.** increased only. **C.** remained the same. **D.** decreased, then increased.	page 64 Earth/Space Science Research Summaries

<table>
<tr><th colspan="4">Table 2: PLAN Sample Test Questions by Score Range
Interpretation of Data Strand, continued</th></tr>
<tr><th>Score Range</th><th>Interpretation of Data</th><th>Sample Test Questions</th><th>Passage Information</th></tr>
<tr><td rowspan="2">20–23</td><td>Translate information into a table, graph, or diagram</td><td>Which of the following graphs of solubility versus pressure best fits the data for hydrogen at 25ºC ?

*A.


B.


C.


D.

</td><td>page 69

Chemistry

Data Representation</td></tr>
<tr><td>Select data from a complex data presentation (e.g., a table or graph with more than three variables; a phase diagram)</td><td>At 100°C and 1 atm, which of the following substances could NOT be dissolved in water?

A. Sodium chloride
B. Potassium nitrate
C. Sucrose
*D. Carbon dioxide</td><td>page 69

Chemistry

Data Representation</td></tr>
</table>

Table 2: **PLAN Sample Test Questions by Score Range**
Interpretation of Data Strand, *continued*

Score Range	***Interpretation of Data***	***Sample Test Questions***	***Passage Information***
24–27	Interpolate between data points in a table or graph	At 25°C and 1.5 atm pressure, the solubility of carbon dioxide in water would probably be closest to: **A.** 0 g/100 g water. **B.** 0.14 g/100 g water. ***C.** 0.21 g/100 g water. **D.** 0.28 g/100 g water.	page 69 Chemistry Data Representation
	Determine how the value of one variable changes as the value of another variable changes in a complex data presentation	Based on the results of Experiment 3 for 2.0% HCl, as the soak time in 4.0% F^- solution increased from 10 min to 50 min, the CO_2 collection time: **A.** increased only. ***B.** increased, then remained the same. **C.** decreased only. **D.** decreased, then remained the same.	page 70 Chemistry Research Summaries
28–32	Extrapolate from data points in a table or graph	For Sphere A, suppose an altitude had been calculated for an elapsed time of 5 sec. What altitude would Sphere A have fallen to in 5 sec ? ***A.** Less than 77.7 m **B.** 77.7 m **C.** 85.8 m **D.** 100.0 m	page 71 Physics Data Representation
	Compare or combine data from a simple data presentation with data from a complex data presentation	According to Figures 2 and 4, approximately how many of Earth's months will it take for Mars's apparent magnitude to go from –1 to +1 ? ***A.** 3 **B.** 6 **C.** 9 **D.** 12	page 72 Physics Data Representation

Table 2: PLAN Sample Test Questions by Score Range
Scientific Investigation Strand

Score Range	*Scientific Investigation*	*Sample Test Questions*	*Passage Information*
13–15			
16–19	Understand the methods and tools used in a simple experiment	Which of the following statements best describes the purpose of the filter paper in Study 2 ? **A.** To absorb all the water poured onto the samples **B.** To add weight to the sample ***C.** To provide a porous container for the soil **D.** To prevent the passage of water through the soil	page 73 Earth/Space Science Research Summaries
20–23	Identify similarities and differences between experiments	Which of the following statements best describes how the design of Study 2 differs from the design of Study 3 ? Study 2 examined how the Pb concentration of samples of groundwater and stream water varied: ***A.** with elevation, while Study 3 examined how the Pb concentration of groundwater and stream water samples varied over time. **B.** with elevation, while Study 3 examined how the Pb concentration of groundwater and stream water samples varied according to the type of soil present. **C.** according to the type of soil present, while Study 3 examined how the Pb concentration of groundwater and stream water samples varied over time. **D.** over time, while Study 3 examined how the Pb concentration of groundwater and stream water samples varied with elevation.	page 64 Earth/Space Science Research Summaries
	Identify a control in an experiment	Which of the following seed samples from Experiments 2 and 3 served as controls? **A.** The treated seed samples from Experiment 2 only **B.** The treated seed samples from Experiments 2 and 3 **C.** The untreated seed samples from Experiment 3 only ***D.** The untreated seed samples from Experiments 2 and 3	page 74 Biology Research Summaries
24–27	Understand a complex experimental design	In Experiment 1, which of the following factors was varied? **A.** Incubation temperature for *S. albus* **B.** Incubation temperature for *S. aureus* ***C.** Incubation time for *S. albus* **D.** Incubation time for *S. aureus*	page 75 Biology Research Summaries
	Determine the experimental conditions that would produce specified results	Based on the results of Experiment 3, at which of the following temperatures would a starch solution treated with amylase for 10 min be expected to produce a positive test for maltose? **A.** 0°C only **B.** Both 0°C and 25°C ***C.** Both 25°C and 37°C **D.** 100°C only	page 76 Chemistry Research Summaries

Table 2: **PLAN Sample Test Questions by Score Range**
Scientific Investigation Strand, *continued*

Score Range	***Scientific Investigation***	***Sample Test Questions***	***Passage Information***
28–32	Determine the hypothesis for an experiment	Which of the following best describes the main purpose of the 3 experiments? **A.** To react various substances with H_2O **B.** To determine why various substances are anhydrous ***C.** To find the percentage of H_2O in various substances **D.** To analyze the hydrates present in margarine and lotion	page 77 Chemistry Research Summaries
	Identify an alternate method for testing a hypothesis	Which of the following procedures could the student have used alternatively to best measure the height of each ball's bounce? **A.** Measuring the total time the ball was in contact with the floor ***B.** Placing an object of known height in the drop area for comparison **C.** Placing an object of unknown height in the drop area for comparison **D.** Measuring the temperature of the ball and the air	page 68 Physics Research Summaries

Table 2: PLAN Sample Test Questions by Score Range

Evaluation of Models, Inferences, and Experimental Results Strand

Score Range	Evaluation of Models, Inferences, and Experimental Results	Sample Test Questions	Passage Information
13–15			
16–19			
20–23	Select a simple hypothesis, prediction, or conclusion that is supported by a data presentation or a model	Which of the following conclusions concerning the germination of corn at 20°C and 35°C is consistent with the results of Experiment 1 ? **A.** No seeds are able to germinate at 20°C or 35°C. ***B.** About half as many seeds germinate at 20°C as at 35°C. **C.** Twice as many seeds germinate at 20°C as at 35°C. **D.** All the seeds germinate at 20°C and 35°C by Day 21.	page 74 Biology Research Summaries
	Identify key issues or assumptions in a model	An assumption of the Social Cohesion Hypothesis is that when a predator is present gazelles are more likely to escape predation if they: **A.** flee individually. ***B.** flee as a herd. **C.** signal the predator. **D.** run toward the predator.	page 78 Biology Conflicting Viewpoints
24–27	Determine whether given information supports or contradicts a simple hypothesis or conclusion, and why	A researcher has claimed that amylase is most active at human body temperature (37°C). Do the results of Experiment 2 support her claim? **A.** Yes; all of the solutions at 37°C produced a positive iodine test. ***B.** Yes; all of the solutions at 37°C produced a negative iodine test. **C.** No; the solutions at 0°C, 25°C, and 200°C produced positive iodine tests. **D.** No; the solutions at 0°C, 25°C, and 100°C produced negative iodine tests.	page 76 Chemistry Research Summaries
	Identify similarities and differences between models	All 4 hypotheses presented in the passage are similar in that they suggest gazelles stot to: **A.** confuse a predator. ***B.** send some type of signal. **C.** produce herd behavior in other gazelles. **D.** decrease their own chance of escape.	page 78 Biology Conflicting Viewpoints

Table 2:	**PLAN Sample Test Questions by Score Range** *Evaluation of Models, Inferences, and Experimental Results* Strand		
Score Range	***Evaluation of Models, Inferences, and Experimental Results***	***Sample Test Questions***	***Passage Information***
28–32	Select a complex hypothesis, prediction, or conclusion that is supported by a data presentation or model	Based on the results of Experiment 2, penicillinase is most effective at destroying penicillin at which of the following pH values? **A.** 5.0 **B.** 6.1 ***C.** 7.4 **D.** 8.5	page 75 Biology Research Summaries
	Use new information to make a prediction based on a model	Houses in many coastal areas are built on stilts to keep the houses above water. According to Scientist 2, which of the following would one most likely predict about the radon hazard in those houses? **A.** Radon would accumulate to high levels in the lowest floor of those houses. **B.** Radon would accumulate to high levels in the highest floor of those houses. **C.** Radon would not be a hazard because the drinking water is aerated inside the houses. ***D.** Radon would not be a hazard because the lowest floor of those houses is not in contact with soil or bedrock.	page 79 Earth/Space Science Conflicting Viewpoints

Thinking Your Way Through the PLAN Test

In our increasingly complex society, students' ability to think critically and make informed decisions is more important than ever. The workplace demands new skills and knowledge and continual learning; information bombards consumers through media and the Internet; familiar assumptions and values often come into question. More than ever before, students in today's classrooms face a future when they will need to adapt quickly to change, to think about issues in rational and creative ways, to cope with ambiguities, and to find means of applying information to new situations.

Classroom teachers are integrally involved in preparing today's students for their futures. Such preparation must include the development of thinking skills such as problem solving, decision making, and inferential and evaluative thinking. These are, in fact, the types of skills and understandings that underlie the test questions on PLAN.

How Can Analyzing Test Questions Build Thinking Skills?

On pages 22–24, you will find an additional passage and sample test questions. The sample test questions provide a link to a strand, a Standard, and a score range. Each sample test question includes a description of the skills and understandings students must demonstrate in order to determine the best answer. The descriptions provide a series of strategies students typically might employ as they work through each test question. Possible flawed strategies leading to the choice of one or more incorrect responses also are offered. Analyzing test questions in this way, as test developers do to produce a Test Question Rationale, can provide students with a means of understanding the knowledge and skills embedded in the test questions and an opportunity to explore why an answer choice is correct or incorrect.

Providing students with strategies such as these encourages them to take charge of their thinking and learning. The sample test questions that appear in Table 2 on pages 14–20 can be used to develop additional Test Question Rationales.

> **"Learning is fundamentally about *making and maintaining connections* . . . among concepts, ideas, and meanings."**
>
> — American Association for Higher Education, American College Personnel Association, & National Association of Student Personnel Administrators, June 1998

The following passage is an example of a Conflicting Viewpoints format. The passage is followed by three questions.

The closest of the 4 Galilean moons that orbit the planet Jupiter is *Io*. Io is unique among the known solar system bodies (other than Earth) in that it has active volcanoes on its surface, indicating high interior heat. Io also appears to have no H_2O (water or ice) on or under its surface. Two astronomers discuss how Io's interior heat is generated.

Astronomer 1

Calculations show that Io's interior is heated almost entirely by tidal effects due to Jupiter. Any other heating effects are negligible. The gravitational field of Jupiter distorts and squeezes Io as Io orbits Jupiter in an elliptical path. This distortion of the moon causes internal friction, which generates the high heat that triggers violent volcanic eruptions.

The fact that the other 3 Galilean moons have significant amounts of H_2O (water or ice) suggests that when Io was formed billions of years ago, it too had H_2O. Over millions of years, the H_2O has been heated and vaporized as a result of tidal effects. The vaporized water then escaped from Io's relatively weak gravity.

Astronomer 2

The heating of Io's interior is caused by radioactive material inside Io. This radioactivity occurs when elements, such as uranium, break apart and decay into other elements. The energy released in the formation of new elements heats the existing material around it.

Studies show that Io probably never had any H_2O. Before Io was formed from smaller pieces, or *planetesimals*, Jupiter's surface heat vaporized any H_2O found in the planetesimals. By the time Io had actually formed, its H_2O was already gone. The other Galilean moons that have large quantities of H_2O are too far from Jupiter to have had H_2O removed from their planetesimals by Jupiter's heat.

For this passage students need to recognize the premise of each hypothesis. They must be able to recognize the ways in which the hypotheses are similar and how they are different. For example, the statement that Io has high interior heat is the basis for both viewpoints.

Test Question Rationale	
Evaluation of Models, Inferences, and Experimental Results	■ Identify key issues or assumptions in a model ■ 20–23 score range

1. Which of the following assumptions is Astronomer 2 making in explaining the effect of the hypothesized radioactive material inside Io?

A. The radioactive material induces tidal stresses inside Io, helping to cool Io's interior.
B. The radioactive material bubbles to the surface and turns to a solid.
C. The radioactive material causes Io to periodically rotate faster, then slower, triggering volcanic eruptions.
***D.** The radioactive material heats the interior of Io.

Question 1 tests Understanding skills. To arrive at the correct answer, choice D, the student must be able to read and understand that Astronomer 2 postulates that the decay of radioactive materials inside Io generates heat that warms Io's interior. Students must realize that they should look at Astronomer 2's viewpoint and NOT Astronomer 1's viewpoint. If the students do not read carefully, they may think that the decay of radioactive material cools the interior of Io rather than heats it, or that radioactive material bubbles to the surface, or that the decay of radioactive materials affects the rotation of Io. None of these points is part of the text of Astronomer 2's viewpoint. Therefore, choices A, B, and C can be eliminated.

Test Question Rationale	
Evaluation of Models, Inferences, and Experimental Results	■ Identify similarities and differences between models ■ 24–27 score range

2. Astronomer 1's hypothesis differs from Astronomer 2's in that Astronomer 1's hypothesis requires which of the following conditions?

F. The presence of radioactive material inside Io
***G.** Io to be periodically deformed as a result of tidal effects
H. Friction to heat the interior of Jupiter
J. Volcanic eruption to occur on Jupiter

Question 2 tests Analysis skills. The correct answer is choice G. The first sentence of Astronomer 1's viewpoint states that Io is heated because of the tidal effects due to Jupiter. The student must read the viewpoints carefully and understand the similarities and differences between the viewpoints. If students misread the question and think they need to base their answer on Astronomer 2's viewpoint instead of that of Astronomer 1, they may select choice F, which is the basis for Astronomer 2's viewpoint. If they don't recognize that both viewpoints are addressing conditions on Io, NOT Jupiter, they may select choices H or J, which address Jupiter's conditions. Students may often select choice H since the phrase "distortion of the moon causes internal friction" is in Astronomer 1's viewpoint; however, that is referring to Io, NOT Jupiter.

Test Question Rationale	
Evaluation of Models, Inferences, and Experimental Results	■ Select a complex hypothesis, prediction, or conclusion that is supported by a data presentation or a model ■ 28–32 score range

3. Io is almost identical in volume and mass to our Moon. If Astronomer 1's hypothesis is correct, why doesn't Earth cause active volcanoes on our Moon today?

A. Earth does not have sufficient radioactive material inside.
B. The Moon has no gravitational effect on Earth.
C. The Moon has no water on its surface.
***D.** Earth's tidal effect on the Moon is not as great as Jupiter's tidal effect on Io.

Question 3 tests Generalization skills. Students must reread both viewpoints carefully and must recognize the basic difference between them: Astronomer 1 states Io is heated by the tidal effects caused by Jupiter; Astronomer 2 states that radioactive decay of materials inside Io heats its interior. Since the question asks about Astronomer 1, the intent is for students to focus on the tidal effect of a larger body on a smaller one. Choice D, which is correct, is the only choice to address tidal effects. If students refer to the wrong viewpoint, they may select choice A since radioactive decay is the main point of Astronomer 2's viewpoint. Neither viewpoint talks about the gravitational effects of a smaller body on a larger one, so choice B can be eliminated. Both viewpoints talk about water on Io; however, choice C's reference to water on the Moon does not explain why Earth doesn't cause active volcanoes on the Moon.

The Assessment-Instruction Link

Why Is It Important to Link Assessment With Instruction?

Assessment provides feedback to the learner and the teacher. It bridges the gap between expectations and reality. Assessment can gauge the learners' readiness to extend their knowledge in a given area, measure knowledge gains, identify needs, and determine the learners' ability to transfer what was learned to a new setting.

When teachers use assessment tools to gather information about their students, then modify instruction accordingly, the assessment process becomes an integral part of teaching and learning. Using assessment to inform instruction can help teachers create a successful learning environment.

Students can use assessment as a tool to help them revise and rethink their work, to help integrate prior knowledge with new learning, and to apply their knowledge to new situations. Connecting assessment to classroom instruction can help both teachers and students take charge of thinking and learning.

As teachers review student performances on various measures, they can reexamine how to help students learn. As Peter Airasian, the author of *Classroom Assessment* says, "Assessment is not an end in itself, but a means to another end, namely, good decision making" (p. 19). Linking assessment and instruction prompts both teachers and students to take on new roles and responsibilities. Through reflecting together on their learning, students and teachers can reevaluate their goals and embark on a process of continuous growth.

> **"*Every* objective, *every* lesson plan, *every* classroom activity, and *every* assessment method should focus on helping students achieve those [significant] outcomes that will help students both in the classroom and beyond."**
>
> — Kay Burke, editor of *Authentic Assessment: A Collection*

Are Your Students Developing the Necessary Skills?

Because PLAN is administered during the tenth grade, it allows for a midpoint review of progress students are making in high school. The PLAN results can be used to provide direction for educational and career planning that will allow for adjustment in students' course work to achieve goals after high school. At this stage in their high school careers, students should be encouraged to explore a range of educational and career options based on their current interests and most recent achievements.

EXPLORE and PLAN are developmentally and conceptually linked to the ACT and thus provide a coherent framework for students and counselors and a consistent skills focus for teachers from Grades 8 through 12.

To facilitate the review of students' progress, PLAN and ACT scores are linked through a common score scale and students receive an estimated ACT Composite score along with their PLAN scores. These scores can be used to evaluate students' readiness for college course work and to provide guidance as they prepare for their transition to college or further training. With an ever-increasing number of high school graduates entering college, it becomes the schools' responsibility to ensure that its graduates have mastered the prerequisite skills necessary for success in entry-level courses.

As students and others review test scores from EXPLORE, PLAN, and the ACT, they should be aware that ACT's data clearly reveal that students' ACT test scores are directly related to preparation for college. Students who take rigorous high school courses, which ACT has defined as core college preparatory courses, achieve much higher test scores than students who do not. ACT has defined core college preparatory course work as four or more years of English, and three or more years each of mathematics, social studies, and natural science.

ACT works with colleges to help them develop guidelines that place students in courses that are appropriate for their level of achievement as measured by the ACT. In doing this work, ACT has gathered course grade and test score data from a large number of first-year students across a wide range of postsecondary institutions. These data provide an overall measure of what it takes to be successful in a standard first-year college course. Data from 98 institutions and over 90,000 students were used to establish the ACT College Readiness Benchmark Scores, which are median course placement scores achieved on the ACT that are directly reflective of student success in a college course.

Success is defined as a 50 percent chance that a student will earn a grade of B or better. The courses are the ones most commonly taken by first-year students in the areas of English, mathematics, social studies, and science, namely English Composition, College Algebra, an entry-level College Social Studies/Humanities course, and College Biology. The ACT scores established as the ACT College Readiness Benchmark Scores are 18 on the English Test, 22 on the Mathematics Test, 21 on the Reading Test, and 24 on the Science Test. The College Readiness Benchmark Scores were based upon a sample of postsecondary institutions from across the United States. The data from these institutions were weighted to reflect postsecondary institutions nationally. The Benchmark Scores are median course placement values for these institutions and as such represent a *typical* set of expectations.

College Readiness Benchmark Scores have also been developed for EXPLORE and for PLAN, to indicate a student's probable readiness for college-level work, in the same courses named above, by the time the student graduates from high school. The EXPLORE and PLAN College Readiness Benchmark Scores were developed using records of students who had taken EXPLORE, PLAN, and the ACT (four years of matched data). Using either EXPLORE subject-area scores or PLAN subject-area scores, we estimated the conditional probabilities associated with meeting or exceeding the corresponding ACT Benchmark Score. Thus, each EXPLORE (1–25) or PLAN (1–32) score was associated with an estimated probability of meeting or exceeding the relevant ACT Benchmark Score. We then identified the EXPLORE and PLAN scores, at Grades 8, 9, 10, and 11, that came the closest to a 0.5 probability of meeting or exceeding the ACT Benchmark Score, by subject area. These scores were selected as the EXPLORE and PLAN Benchmark Scores.

All the Benchmark Scores are given in Table 3. Note that, for example, the first row of the table should be read as follows: An eighth-grade student who scores 13, or a ninth-grade student who scores 14, on the EXPLORE English Test has a 50 percent probability of scoring 18 on the ACT English Test; and a tenth-grade student who scores 15, or an eleventh-grade student who scores 17, on the PLAN English Test has a 50 percent probability of scoring 18 on the ACT English Test.

Table 3: **College Readiness Benchmark Scores**

	EXPLORE Test Score		**PLAN Test Score**		**ACT**
Subject Test	**Grade 8**	**Grade 9**	**Grade 10**	**Grade 11**	**Test Score**
English	13	14	15	17	18
Mathematics	17	18	19	21	22
Reading	15	16	17	19	21
Science	20	20	21	23	24

Using Assessment Information to Help Support Low-Scoring Students

Students who receive a Composite score of 16 or below on PLAN will most likely require additional guidance and support from their teachers and family in order to meet their academic goals, particularly if one of those goals is to attend a four-year college or university.

College admission policies vary widely in their level of selectivity. ACT Composite scores typically required by colleges having varying levels of selectivity are shown in Table 4. This information provides only general guidelines. There is considerable overlap among admission categories, and colleges often make exceptions to their stated admission policies.

Table 4: **The Link Between ACT Composite Scores and College Admission Policies**

Admission Policy	Typical Class Rank of Admitted Students	Typical ACT Composite Scores of Admitted Students
Highly Selective	Majority of accepted freshmen in top 10% of high school graduating class	25–30
Selective	Majority of accepted freshmen in top 25% of high school graduating class	21–26
Traditional	Majority of accepted freshmen in top 50% of high school graduating class	18–24
Liberal	Some of accepted freshmen from lower half of high school graduating class	17–22
Open	All high school graduates accepted to limit of capacity	16–21

A student's PLAN Composite score is one indicator of the student's readiness for college-level work. For each student's PLAN Composite score, an estimated ACT score range is reported. The estimated ACT Composite score range refers to the score a student would be expected to obtain in the fall of his or her senior year. The estimated fall twelfth-grade score ranges for students who take PLAN in the fall of tenth grade are reported in Table 5.

Table 5 indicates that, for a PLAN Composite score of 13 in the fall of tenth grade, the lower limit of the estimated fall twelfth-grade ACT Composite score range is given as 13 and the upper limit is given as 17. That is, an estimated ACT Composite score range of 13 to 17 is reported for students who receive PLAN Composite scores of 13 when tested in the fall of tenth grade.

In interpreting the estimated ACT Composite score ranges, it's important to note that EXPLORE, PLAN, and the ACT are curriculum-based testing programs. This is one reason ACT expects that some students will fall short of or improve upon their estimated ACT score ranges. If students do not maintain good academic work in high school, their actual ACT Composite scores may fall short of their estimated score ranges. The converse is also true; some students who improve their academic performance may earn ACT Composite scores higher than estimated.

As students review their PLAN test scores, they should be encouraged to think about their postsecondary education or training plans. Test scores should be discussed in the context of students' future goals, previous academic preparation, and plans for future high school course work. As educators and parents look over students' content-area test scores, the way students' scores match up with their goals will become clear. For example, a student who wishes to become an engineer will need a solid science background. A high Science Test score can be used as evidence that the goal is realistic. A low score (or subscore) suggests the student should consider ways of improving his or her scientific knowledge and skills through additional course work and/or added effort in the area.

Table 5: **Estimated ACT Composite Score Ranges**

PLAN Composite Score	**Estimated ACT Composite Score Range**	
	Low Score	**High Score**
1	8	10
2	8	10
3	8	10
4	8	11
5	8	11
6	9	12
7	10	13
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9	11	14
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18	19	23
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21	22	26
22	23	27
23	24	28
24	26	30
25	26	30
26	27	31
27	28	32
28	29	33
29	30	33
30	31	34
31	33	35
32	33	35

"A rigorous high school curriculum is often the strongest predictor of entering college and earning a degree. . . . This suggests that for students who plan to go to college, demanding coursework as early as eighth grade will increase their chances for college success. As [high school] course requirements become standard, it is important to ensure that the corresponding course content prepares students for the rigors of college" (Noeth & Wimberly, 2002, p. 17).

In addition to planning for high school course work, taking remedial classes if necessary, and beginning to match career goals to known talents, tenth-grade students who want to attend a four-year college or university should begin educating themselves about such schools. Some students, particularly those whose parents did not attend college, may not have access to information about postsecondary education. "Though many students . . . attending urban schools may have the desire and expectation, they may not have the skills, knowledge, and information they need to enter and complete a postsecondary program. Many . . . do not have the informational resources, personal support networks, continual checkpoints, or structured programs to make college exploration and planning a theme throughout their daily lives. . . . Students need their schools, parents, and others to help them plan for college and their future careers" (Noeth & Wimberly, 2002, p. 4).

What Does It Mean to Be a Low-Scoring Student?

Low-achieving students tend to be those students who score low on standardized tests. Students who slip behind are the likeliest to drop out and least likely to overcome social and personal disadvantages.

According to Judson Hixson, a researcher at the North Central Regional Educational Laboratory (NCREL), students who are at risk should be considered in a new light:

> Students are placed "at risk" when they experience a significant mismatch between their circumstances and needs, and the capacity or willingness of the school to accept, accommodate, and respond to them in a manner that supports and enables their maximum social, emotional, and intellectual growth and development.
>
> As the degree of mismatch increases, so does the likelihood that they will fail to either complete their elementary and secondary education, or more importantly, to benefit from it in a manner that ensures they have the knowledge, skills, and dispositions necessary to be successful in the next stage of their lives—that is, to successfully pursue postsecondary education, training, or meaningful employment and to participate in, and contribute to, the social, economic, and political life of their community and society as a whole.
>
> The focus of our efforts, therefore, should be on enhancing our institutional and professional capacity and responsiveness, rather than categorizing and penalizing students for simply being who they are. (Hixson, 1993, p. 2)

Hixson's views reveal the necessity of looking at all the variables that could affect students' performance, not just focusing on the students themselves.

Low-achieving students may demonstrate some of the following characteristics:

- difficulty with the volume of work to be completed;
- low reading and writing skills;
- low motivation;
- low self-esteem;
- poor study habits;
- lack of concentration;
- reluctance to participate in class or to ask for help with tasks/assignments; and
- test anxiety.

Many of these characteristics are interconnected. For example, a low-scoring student cannot complete the volume of work a successful student can if it takes a much longer time for that low-scoring student to decipher text passages because of low reading skills. There is also the issue of intrinsic motivation: students may have little desire to keep trying if they do not habitually experience success.

Some low-scoring students may not lack motivation or good study habits, but may still be in the process of learning English; still others may have learning disabilities that make it difficult for them to do complex work in one or two content areas.

Again, we must not focus only on the students themselves, but also consider other variables that could affect their academic performance, such as

- job or home responsibilities that take time away from school responsibilities;
- parental attitude toward and involvement in students' school success;
- students' relationships with their peers;
- lack of adequate support and resources; and
- lack of opportunities.

For example, some students who score low on tests are never introduced to a curriculum that challenges them or that addresses their particular needs: "Much of the student stratification within academic courses reflects the social and economic stratification of society. Schools using tracking systems or other methods that ultimately place low-income and marginal students in lower-level academic courses are not adequately preparing them to plan for postsecondary education, succeed in college, and prepare for lifelong learning" (Noeth & Wimberly, 2002, p. 18).

As Barbara Means and Michael Knapp have suggested, many schools need to reconstruct their curricula, employing instructional strategies that help students to understand how experts think through problems or tasks, to discover multiple ways to solve a problem, to complete complex tasks by receiving support (e.g., cues, modifications), and to engage actively in classroom discussions (1991).

Many individuals and organizations are interested in helping students succeed in the classroom and in the future. For example, the Network for Equity in Student Achievement (NESA), a group of large urban school systems, and the Minority Student Achievement Network (MSAN), a group of school districts in diverse suburban areas and small cities, are organizations that are dedicated to initiating strategies that will close the achievement gap among groups of students. Many schools and districts have found participation in such consortia to be helpful.

According to Michael Sadowski, editor of the *Harvard Education Letter,* administrators and teachers who are frustrated by persistent achievement gaps within their school districts "have started to look for answers within the walls of their own schools. They're studying school records, disaggregating test score and grade data, interviewing students and teachers, administrating questionnaires—essentially becoming researchers—to identify exactly where problems exist and to design solutions" (Sadowski, 2001, p. 1).

A student may get a low score on a standardized test for any of a number of reasons. To reduce the probability of that outcome, the following pages provide information about factors that affect student performance as well as some suggestions about what educators and students can do before students' achievement is assessed on standardized tests like PLAN.

What Are Some Factors That Affect Student Performance?

Many factors affect student achievement. Diane Ravitch, a research professor at New York University, has identified several positive factors in her book *The Schools We Deserve: Reflections on the Educational Crisis of Our Time* (1985, pp. 276 and 294). These factors, which were common to those schools that were considered effective in teaching students, include

- a principal who has a clearly articulated vision for the school, and the leadership skills to empower teachers to work toward that vision;
- a strong, clearly thought-out curriculum in which knowledge gained in one grade is built upon in the next;
- dedicated educators working in their field of expertise;
- school-wide commitment to learning, to becoming a "community of learners";
- a blend of students from diverse backgrounds;
- "high expectations for all" students; and
- systematic monitoring of student progress through an assessment system.

There are also factors that have a negative impact on student achievement. For example, some students "may not know about, know how, or feel entitled to take academic advantage of certain opportunities, like college preparatory courses, college entrance exams, and extracurricular learning opportunities" (Goodwin, 2000, p. 3).

All students need to be motivated to perform well academically, and they need informed guidance in sorting out their educational/career aspirations. Teachers who challenge their students by providing a curriculum that is rigorous and relevant to their world and needs (Brewer, Rees, & Argys, 1995; Gay, 2000), and who have a degree and certification in the area in which they teach (Ingersoll, 1998) and ample opportunities to collaborate with their peers (McCollum, 2000), are more likely to engender students' success in school.

Making the Invisible Visible

Using assessment information, such as that provided by the EXPLORE, PLAN, and ACT tests in ACT's Educational Planning and Assessment System (EPAS), can help bring into view factors that may affect—either positively or negatively—student performance. Reviewing and interpreting assessment information can encourage conversations between parents and teachers about what is best for students. Using data is one way of making the assumptions you have about your students and school, or the needs of students, visible.

Collecting assessment information in a systematic way can help teachers in various ways. It can help teachers see more clearly what is happening in their classrooms, provide evidence that the method of teaching they're using really works, and determine what is most important to do next. As teachers become active teacher-researchers, they can gain a sense of control and efficacy that contributes to their sense of accomplishment about what they do each day.

There are many different types of assessment information that a school or school district can collect. Some types yield quantitative data (performance described in numerical terms), others qualitative data (performance described in nonnumerical terms, such as text, audio, video, or photographs). All types, when properly analyzed, can yield useful insights into student learning. For example, schools and teachers can collect information from

- standardized tests (norm- or criterion-referenced tests);
- performance assessments (such as portfolios, projects, artifacts, presentations);
- peer assessments;
- progress reports (qualitative, quantitative, or both) on student skills and outcomes;
- self-reports, logs, journals; and
- rubrics and rating scales.

Reviewing student learning information in the context of demographic data may also provide insight and information about specific groups of students, like low-scoring students. Schools therefore would benefit by collecting data about

- enrollment, mobility, and housing trends;
- staff and student attendance rates and tardiness rates;
- dropout, retention, and graduation rates;
- gender, race, ethnicity, and health;
- percent of free/reduced lunch and/or public assistance;
- level of language proficiency;
- staff/student ratios;
- number of courses taught by teachers outside their endorsed content area;
- retirement projections and turnover rates; and
- teaching and student awards.

What Can Educators and Students Do Before Students Take Standardized Tests?

Integrate assessment and instruction. Because PLAN is curriculum-based, the most important prerequisite for optimum performance on the test is a sound, comprehensive educational program. This "preparation" begins long before any test date. Judith Langer, the director of the National Research Center on English Learning and Achievement, conducted a five-year study that compared the English programs of typical schools to those that get outstanding results. Schools with economically disadvantaged and diverse student populations in California, Florida, New York, and Texas predominated the study. Langer's study revealed that in higher performing schools "test preparation has been integrated into the class time, as part of the ongoing English language arts learning goals." This means that teachers discuss the demands of high-stakes tests and how they "relate to district and state standards and expectations as well as to their curriculum" (Langer, 2000, p. 6).

Emphasize core courses. ACT research conducted in urban schools both in 1998 and 1999 shows that urban school students can substantially improve their readiness for college by taking a more demanding sequence of core academic courses in high school. Urban students taking a more rigorous sequence of courses in mathematics and science and finding success in those courses score at or above national averages on the ACT. Regardless of gender, ethnicity, or family income, those students who elect to take four or more years of rigorous English courses and three or more years of rigorous course work in mathematics, science, and social studies earn higher ACT scores and are more successful in college than those who have not taken those courses (ACT & Council of Great City Schools, 1999). Subsequent research has substantiated these findings and confirmed the value of rigor in the core courses (ACT, 2004; ACT & The Education Trust, 2004).

Teach test-taking strategies. Students may be helped by being taught specific test-taking strategies, such as the following:

- Learn to pace yourself.
- Know the directions and understand the answer sheet.
- Read carefully and thoroughly.
- Answer easier questions first; skip harder questions and return to them later.
- Review answers and check work, if time allows.
- Mark the answer sheet quickly and neatly; avoid erasure marks on the answer sheet.
- Answer every question (you are not penalized for guessing on PLAN).
- Become familiar with test administration procedures.
- Read all the answer choices before you decide which is the best answer.

Students are more likely to perform at their best on a test if they are comfortable with the test format, know appropriate test-taking strategies, and are aware of the test administration procedures. Test preparation activities that help students perform better in the short term will be helpful to those students who have little experience taking standardized tests or who are unfamiliar with the format of PLAN.

What Do the PLAN Science Test Results Indicate About Low-Scoring Students?

Students who score below 16 on the PLAN Science Test are likely to have some or all of the knowledge and skills described in the PLAN Science College Readiness Standards for the 13–15 range. In fact, they may well have some of the skills listed in the 16–19 range. Low-scoring students may be able to demonstrate skills in a classroom setting that they are not able to demonstrate in a testing situation. Therefore, these students need to become more consistent in demonstrating these skills in a variety of contexts and situations.

The EPAS Science College Readiness Standards indicate that students who score below 16 tend to have the ability to

- Select a single piece of data (numerical or nonnumerical) from a simple data presentation (e.g., a table or graph with two or three variables; a food web diagram)
- Identify basic features of a table, graph, or diagram (e.g., headings, units of measurement, axis labels)

In other words, these students typically can read basic graphs, uncomplicated diagrams, or tables of data displaying two different variables. They can read and comprehend information in a written description of a simple science experiment or in a text that describes or discusses an uncomplicated scientific observation. They can understand some basic scientific terminology and know the most familiar units of measure. These students typically demonstrate an ability to work with straightforward, simple displays of data similar to those they have seen in their textbooks and classes.

These students likely need assistance in applying simple data interpretation skills to more unfamiliar or complex presentations of data. They also generally need help in developing facility in reading and interpreting text written specifically to describe scientific observations, research, and results.

What Does Research Say About Scientifically Literate Students?

It is important to distinguish between ***science literacy*** and ***scientific literacy.*** Science literacy focuses on gaining specific scientific or technical knowledge. Science literacy emphasizes practical results and stresses short-term goals, such as training members of society with specific facts and skills (Maienschein, 1998). Training a technician to operate a spectrometer to process lab samples is an example of science literacy. Scientific literacy, in comparison, entails scientific ways of knowing and the processes of thinking critically and creatively. While a lab technician may be science-literate in that he or she is able to operate a spectrometer, he or she may not have the scientific literacy skills needed to interpret the results and use the information in an appropriate manner. Scientific literacy can only be achieved over the long term. Scientific literacy has emerged as a central goal of science education. The thought processes developed during the education of a scientifically literate population help individuals to be adaptable, to be able to critically examine issues, to solve problems, to realize the impact of science knowledge on their lives, and to develop communication skills with respect to science topics. As students grow in scientific literacy by learning science thinking and process skills such as analyzing, formulating models, and inferring, they improve their reading, mathematics, and oral and written communication skills at the same time (Ostlund, 1998).

There are different types of scientific literacy. In a narrow sense, scientifically literate students are able to read and interpret graphs displaying scientific information, read and write passages that include scientific vocabulary, and use scientific terminology appropriately. Some have applied the term ***functional scientific literacy*** to these skills and abilities. A second type of scientific literacy is ***conceptual procedural literacy,*** in which students are familiar with the concepts and principles of science and possess an understanding of the procedures and processes that make science a unique way of knowing. Students who exhibit conceptual procedural literacy are able to design an experiment that is a valid test of a hypothesis or to pose a question that can be tested by scientific methods. ***Multidimensional scientific literacy*** is a third type of scientific literacy, one in which students develop an understanding of the different aspects of science, such as the nature of science and technology, the history of scientific ideas, and the role of science in personal life and society (Yager, 1993). Students who exhibit this last type of scientific literacy can engage in a scientific discussion of controversial issues and apply scientific information in personal decision making.

Science reasoning, such as that assessed by the PLAN Science Test, is a common thread across these three types of scientific literacy. Development of a familiarity with science, of science reasoning skills, and of the ability to use scientific concepts empowers students for lifelong learning. Teaching and learning science in ways that reflect how science is practiced lead to a greater understanding of the connections that make the concepts and theories of science manageable.

What Can Be Done to Help Students Effectively Develop Scientific Literacy?

George Nelson, Director for Project 2061, states that "Effective education for science literacy requires that every student be frequently and actively involved in exploring nature in ways that resemble how scientists work" (Nelson, 1999, p. 16). Some of the qualities of this "effective education" are science activities that

- are inquiry-based/problem-centered/hands-on;
- allow learning from the concrete to the abstract;
- allow learning from the local to the global;
- require both cooperative and individual performance;
- give opportunities for learner self-evaluation;
- use interdisciplinary connections;
- give students a sense of ownership of the inquiry;
- focus on applying appropriate investigational and analytical strategies;
- emphasize attitudes, problem solving, critical thinking, decision making, applications, technology, and societal issues; and
- reflect current understanding of the nature of the learner.

(Adapted from Bybee & DeBoer, 1994)

Another way to develop a student's scientific literacy is to conclude a science inquiry by requiring students to rephrase the primary concepts in their own words and to support their ideas with data or information.

What Knowledge and Skills Are Low-Scoring Students Ready to Learn?

For students who score below 16 on the PLAN Science Test, their target achievement outcomes could be the College Readiness Standards listed in the 16–19 range of the Interpretation of Data and Scientific Investigation strands. Those students should also have target achievement outcomes that help them begin to develop the skills and understandings included in the 20–23 range of the Evaluation of Models, Inferences, and Experimental Results strand. The list below summarizes the desirable target achievements.

- Select two or more pieces of data from a simple data representation
- Understand basic scientific terminology
- Find basic information in a brief body of text
- Determine how the value of one variable changes as the value of another variable changes in a simple data presentation
- Understand the methods and tools used in a simple experiment

In addition to working toward these skills, students could learn how to create simple graphic presentations of data. These presentations should include, but are not limited to, vertical and horizontal bar graphs and line graphs (using linear scales and displaying one or more plots). Students could learn how to use any of the types of graphics mentioned above to compare data points, interpret trends in the data, or make basic conclusions or predictions. They will likely need practice reading and understanding uncomplicated written descriptions of scientific phenomena and basic experiments and identifying at least one variable and, perhaps, a control in an experiment. They should become familiar with basic scientific terminology and units of measure and work to perform simple experiments and gather data.

By no means should these be seen as limiting or exclusive goals. As stated earlier, it is important to use multiple sources of information to make instructional decisions and to recognize that individual students learn at different rates and in different sequences. What's important is to get students doing science.

What Strategies/Materials Can Teachers Use in Their Classrooms?

According to Bryan Goodwin, senior program associate at the Mid-continent Research Education Laboratory (McREL), "it is important to note that improving the performance of disenfranchised students does not mean ignoring other students. Indeed, many of the changes advocated—such as making curricula more rigorous and creating smaller school units—will benefit all students" (Goodwin, 2000, p. 6). Means and Knapp (1991) express a similar view:

> A fundamental assumption underlying much of the curriculum in America's schools is that certain skills are "basic" and must be mastered before students receive instruction on more "advanced" skills, such as reading comprehension, written composition, and mathematical reasoning. . . . Research from cognitive science questions this assumption and leads to a quite different view of children's learning and appropriate instruction. By discarding assumptions about skill hierarchies and attempting to understand children's competencies as constructed and evolving both inside and outside of school, researchers are developing models of intervention that start with what children know and provide access to explicit models of thinking in areas that traditionally have been termed "advanced" or "higher order." (p. 1)

At-risk students can benefit from the same types of strategies used to develop scientific literacy in any student. Horton and Hutchinson (1997) state that scientific literacy continuously develops when the science curriculum incorporates a wide variety of learning episodes. Keefer (1998) lists some criteria for designing an inquiry-based activity. These include:

- Students must have a problem to solve.
- Students must know they can solve the initial problem.
- Students must have background information that is either provided to them or that they can acquire themselves.
- Students should experience success.

Schwartz (1987) states that hands-on experience, begun early and continuing throughout the schooling of at-risk students, is important in successfully developing scientific literacy in that population. Other successful strategies for at-risk students include providing a cooperative classroom environment that uses student groups, smaller classes, adequate time-on-task, and extracurricular learning opportunities.

Pages 38–45 provide a teacher-developed activity that could be used in a classroom for all students, not just those who have scored low on a standardized assessment like PLAN. The students are asked to perform a simple science investigation involving the concept of rocket propulsion. In this activity, students are asked to perform a simple lab activity, to collect and graph data, and to draw conclusions from the results. They are also asked to perform some simple mathematical analyses during the activity. Two simple scoring rubrics are included that could be used by the teacher to assess student learning and by the students for self-evaluation. One rubric assesses an oral presentation given by the groups of students that worked together on the lab activity. The second rubric assesses a written laboratory report each student will write. Also included are suggestions for other related investigations.

How Is the Activity Organized?

A template for the instructional activity appears on page 37. Since the instructional activity has multiple components, an explanation of each is provided below.

A The primary *Science Strands* are displayed across the top of the page.

B The *Guiding Principles* section consists of one or more statements about instruction, assessment, thinking skills, student learning, and other educationally relevant topics.

C The *Title and Subject Area(s)/Course(s)* information allows you to determine at a glance the primary focus of the activity and whether it might meet the needs of your student population.

D The *Purpose* statement describes knowledge and skills students may have difficulty with and what will be done in the activity to help them acquire that knowledge and skills.

E The *Overview* section provides a brief description of how the knowledge and skills listed in the purpose statement will be taught and suggests an estimated time frame for the entire activity.

F The *Links to College Readiness Standards* section indicates the primary knowledge and skills the activity will focus on. These statements are tied directly to the strands listed at the top of the page.

G The next section, *Description of the Instructional Activity,* is divided into three interrelated parts: Materials/Resources, Introduction, and Suggested Teaching Strategies/Procedures. The section provides suggestions for engaging students in the activity, and gives related topics and tasks. The activity addresses a range of objectives and modes of instruction, but it emphasizes providing students with experiences that focus on reasoning and making connections, use community resources and real-life learning techniques, and encourage students to ask questions—questions leading to analysis, reflection, and further study and to individual construction of meanings and interpretations.

H Valuable *Comments/Tips from Classroom Teachers* are provided for the activity. As the title indicates, this text box includes ideas from current classroom teachers.

I The *Suggestions for Assessment* section offers ideas for documenting and recording student learning. This section describes two types of assessments: Embedded Assessments and Summative Assessments. Embedded Assessments are assessments that inform you as to where your students currently are in the learning process (a formative assessment that is primarily teacher developed and is integral to the instructional process—at times the instruction and assessment are indistinguishable). The second type of assessment is a Summative Assessment (a final assessment of students' learning), which provides a description of the knowledge and skills students are to have mastered by the end of the activity and the criteria by which they will be assessed.

J The *Links to Ideas for Progress* section provides statements that suggest learning experiences (knowledge and skills to be developed) that are connected to the Suggested Strategies/Activities.

K The *Suggested Strategies/Activities* section provides a brief description of ways to reteach the skills or content previously taught or to extend students' learning.

This teacher-developed activity provides suggestions, not prescriptions. You are the best judge of what is necessary and relevant for your students. Therefore, we encourage you to review the activity, modifying and using those suggestions that apply, and disregarding those that are not appropriate for your students. As you select, modify, and revise the activity, you can be guided by the statements that appear in the Guiding Principles box at the beginning of the activity.

Linking Instruction and Assessment

Strand(s): A

Guiding Principles

- B
-
-

Title C

Subject Area(s)/Course(s)

Purpose D

Overview E

Links to College Readiness Standards

- F
-
-

Description of the Instructional Activity

Materials/Resources

- G
-
-

Introduction—

Suggested Teaching Strategies/Procedures—

Comments/Tips from Classroom Teachers:

H

Suggestions for Assessment I

Embedded Assessment (name of assessment)—

Embedded Assessment (name of assessment)—

Summative Assessment (name of assessment)—

Enhancing Student Learning

Links to Ideas for Progress J

-
-
-

Suggested Strategies/Activities K

Guiding Principles

- "In learning science, students need time for exploring, making observations, taking wrong turns, and doing things over." (Nelson, 1999, p. 16)

Rocket Propulsion–It's a Gas!

Ninth- and Tenth-Grade Physics

Purpose

Students can benefit from practice in basic science process skills, such as observation and use of measurement tools. Students will be able to strengthen their scientific investigation skills by formulating a hypothesis, identifying and controlling variables, collecting and analyzing data, and drawing conclusions that are supported by the collected data.

Overview

Students will perform a series of experiments over seven or eight class periods (45 minutes each) to examine how varying the ratio of 2 fuel components in a mixture affects the distance travelled by a "rocket." Role-playing as aeronautical engineers, students will collect data and then analyze those data to determine what effect changing the independent variable has on the dependent variables. They will perform some simple mathematical calculations as part of the data analysis. Finally, they will give an oral presentation to the class and then write a final report.

Links to College Readiness Standards

- Select two or more pieces of data from a simple data presentation
- Translate information into a table, graph, or diagram
- Understand the methods and tools used in a simple experiment
- Determine how the value of one variable changes as the value of another variable changes in a simple data presentation
- Understand a simple experimental design
- Select a simple hypothesis, prediction, or conclusion that is supported by two or more data presentations or models

Description of the Instructional Activity

Materials/Resources

- Large protractor
- 100 g baking soda
- 300 mL white vinegar
- Spoon or spatula
- Meterstick or tape measure
- Graduated cylinder
- 500 mL beaker
- Rubber stoppers (#3 and #4)
- Rocket Propulsion—It's a Gas! Student Information Sheet (pp. 42–43)
- Modeling clay (optional)
- Safety goggles
- White bathroom tissue (toilet paper)
- Brown lunch sack
- Balance
- File folder
- Eyedropper
- Large box
- 20 oz (591 mL) plastic bottle with cap
- Optional Assessments:
  - ✓ Oral Presentation Rubric (p. 44)
  - ✓ Written Lab Report Rubric ("NASA Report") (p. 45)

Linking Instruction and Assessment

Strands: *Interpretation of Data; Scientific Investigation; Evaluation of Models, Inferences, and Experimental Results*

Introduction—Newton's Third Law of Motion states that "for every action there is an equal and opposite reaction." A variety of objects are propelled using this principle, from skateboards to rockets. For skateboarders, when a foot is used to push off the ground in one direction (the "action"), the skateboard moves in the opposite direction (the "reaction"). The human body's biochemical energy powers the leg muscles used to produce the initial "action." Rockets operate using this third law of motion.

Students will investigate one of the oldest type of rockets—chemical rockets. Chemical rockets rely on propulsion that results when two or more chemicals are mixed together. Both spacecraft and fireworks operate using chemical propulsion. The reaction produces hot gases that can be forced out of a small nozzle to produce propulsion in the opposite direction. For example, the space shuttle's main engines use a hydrogen and oxygen reaction that produces hot gases. These gases shoot out through the main engine nozzles to propel the shuttle forward.

The activity can be introduced by having each student research the basics of rocketry and produce a short paper or visual presentation about the major features of rocket design and the similarities and differences in solid fuel and liquid fuel propulsion systems. Students' research can be evaluated to determine if they cover the basic features of rocket design and the requirements for a good rocket fuel. The information in their reports can be reinforced by showing film/video clips of model rocket or full-scale rocket launches. Print material on rocketry can be obtained at www.nasa.gov/pdf/58269main_Rockets.pdf.

Suggested Teaching Strategies/Procedures— Students will work in groups of four and form an aeronautical design company that will write a report to win a government contract to produce rocket fuel. In order to win the contract, each aeronautical design company will investigate and analyze the interactions of two different variables that will affect the rocket's flight—the amount of solid rocket fuel (baking soda), and the amount of liquid rocket fuel (vinegar). Baking soda and vinegar will be used to produce carbon dioxide gas that will provide the needed pressure to propel the rocket.

For this activity, the chemical reaction in the rocket fuel is as follows:

$$\underset{\text{vinegar}}{CH_3COOH} + \underset{\text{baking soda}}{NaHCO_3} \rightarrow \underset{\text{sodium acetate}}{CH_3COONa} + \underset{\text{water}}{H_2O} + \underset{\text{carbon dioxide}}{CO_2}$$

The carbon dioxide gas produced is what propels the rocket. Also, this reaction is *exothermic,* which means that the reaction releases heat.

Each group of students should use a 20 oz plastic bottle to serve as the "external fuel tank." Next, the group must select a rubber stopper to be their "rocket." The stopper must be the correct size so it fits snugly into the mouth of the bottle but does not fit so tightly that it will not be forced out by the gas produced in the chemical reaction.

Comments/Tips from Classroom Teachers:

Supervise students to be sure they do not use large quantities of both rocket fuel components. The gases that build up may split the plastic bottle if the stopper is wedged too tightly into the mouth of the bottle.

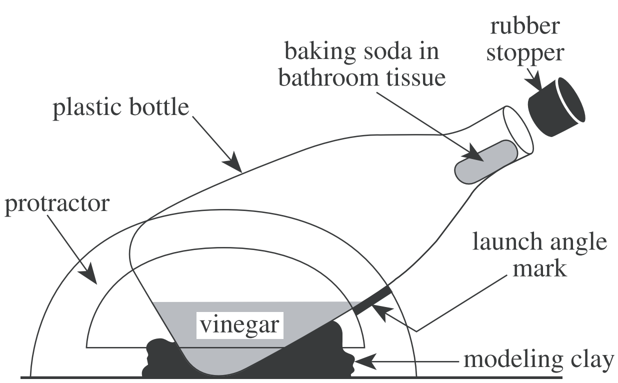
The fuel will be prepared by measuring the respective amounts of vinegar and baking soda that the students have decided to use for their first trial. The baking soda will be wrapped (by folding) or rolled (like a cylinder) in bathroom tissue. This bathroom tissue will allow the vinegar contact with the baking soda and will break apart after it contacts the liquid. Another possible fuel mixture is water as the liquid fuel and a crushed, sodium bicarbonate/citric acid antacid tablet as the solid fuel.

Linking Instruction and Assessment

Strands: *Interpretation of Data; Scientific Investigation; Evaluation of Models, Inferences, and Experimental Results*

The teacher should clearly explain the procedure to be followed in conducting the investigation. Safety issues should be covered, including eye protection, chemical handling, and safe disposal of waste. A general explanation about how science investigations are typically performed (generate hypothesis, design experiment, perform experiment, analyze data, draw conclusions), how hypotheses are generated, how variables are controlled, and how conclusions are made would be helpful. The basic format of a hypothesis should be the "If . . ., then . . ." statement. For example, the teacher could help the students create the following hypothesis: "If the ratio of baking soda to vinegar increases, then the distance flown by the rocket. . . ." The teacher should also emphasize the need for consistency in experimental techniques from trial to trial. A Student Information Sheet is provided (see pages 42–43) that provides the experimental procedure and lists other guidelines for collecting data.

A launch area should be chosen to allow enough room for unrestricted rocket flight. A long hallway with little traffic works best. When a group is cleared by the teacher to launch, the students should mark clearly on a protractor the assigned launch angle (40°). The vinegar is added to the bottle and the baking soda, carefully wrapped/rolled in bathroom tissue, is carefully inserted into the mouth of the bottle. The packet should rest as much as possible on the neck of the bottle and away from the vinegar (see the figure).



After putting on safety goggles, students should carefully stopper the bottle, ensuring that the stopper is in the bottle as straight and as tight as possible so that the maximum amount of pressure can build up. When the bottle has been properly stoppered, the student holding the bottle at the launch angle should carefully give the bottle a little shake, which will make the bathroom tissue packet drop into the vinegar and start the reaction. The bottle should then be quickly returned to the launch angle.

Note: If there is no launch in 10–15 seconds, have the students carefully remove the stopper from the bottle, while pointing the bottle away from themselves and others, and repeat the launch procedure.

Modeling clay can be used to help support the bottle at the correct launch angle. Care should be taken to ensure that the bottle is aimed directly down the center of the hallway and that no one is directly in front of the bottle. If the rocket strikes the walls or ceilings during its flight, the group will earn a government "fine" as a penalty (assigned by the teacher).

Other students in the group, wearing safety goggles, will need to stand along the walls in the hallway and mark the point where the rubber stopper first touches the ground, ceiling, or wall. Students will need to measure to that point (official distance traveled) using metersticks or a tape measure and record the distance.

Comments/Tips from Classroom Teachers:

Students should not cap the bottle after launching, since the reaction may still be taking place. The sodium acetate that is a product of the reaction should be diluted with water by washing out the bottle prior to the next trial. Students should avoid getting the product on them because it may cause some skin or eye irritation.

Students need to analyze the data obtained from each launch and determine whether they want to modify the amount of either fuel component in subsequent sets of launches to achieve the maximum flight distance. Students will quickly learn how the smallest deviation from center will translate into a wide angle over a large distance, resulting in the rocket going out-of-bounds and hitting the wall.

Linking Instruction and Assessment

Strands: *Interpretation of Data; Scientific Investigation; Evaluation of Models, Inferences, and Experimental Results*

While conducting the investigations, Students should follow specific safety and "government regulations" associated with the activity. Each aeronautical design company will calculate the "total cost" of the rocket fuel research and design (R&D). This total cost is the cost of fuel components plus any fines. They will also determine the *cost-to-distance ratio* (total cost [$] / total distance [cm]). Students will conclude the "research and development phase" of their rocket activity by explaining and demonstrating their best rocket fuel mixture during a final launch. It is during this final launch phase that the government verifies the exact amount of fuel used and records an official distance traveled. Each group will submit a written lab report that details their rocket fuel testing and final proposal.

Suggestions for Assessment

Embedded Assessment (Report on Rockets and Rocket Fuels)—Students will present their reports (a paper or visual presentation) to the entire class to show the information they have gathered on rocket design and different rocket fuels. The reports should discuss:

- rocket shape and why certain shapes are better for traveling through the air than others;
- rocket design elements, such as fins, and what function they perform;
- at least two different types of rocket fuels, their chemical components, and how they are incorporated in a rocket's design.

Embedded Assessment (Oral Presentation Rubric)—Each group of students will present their results to the entire class using graphs they have created to show their data and conclusions. The groups should be provided with the oral presentation rubric before starting on their presentation so that the students will know what criteria are to be used in the evaluation of their presentation. Ideally, each member of the group should participate equally in the oral presentation. An Oral Presentation Rubric is presented on page 44.

Summative Assessment (Written Lab Report Rubric, "NASA Report")—Each group of students will write a lab report, which includes the variables being tested, cost analyses of the R&D phase, tables of data, conclusions about whether the data supported the hypotheses, the answers to questions about possible sources of error in the experiment, and an overall recommendation that integrates math and writing skills. A Written Lab Report Rubric is provided on page 45.

Enhancing Student Learning

Links to Ideas for Progress

- Formulate hypotheses, predictions, or conclusions by comparing and contrasting several different sets of data from different experiments
- Design and carry out additional scientific inquiries to answer specific questions
- Carry out scientific investigations in which the importance of accuracy and precision is stressed

Suggested Strategies/Activities

This activity could be expanded by having students investigate:

- whether changing the shape or mass of the stopper affects flight distance,
- whether varying the launch angle affects the flight distance and height reached by the rocket,
- whether heating the vinegar increases the rate of the chemical reaction,
- why repeated rocket launches under identical conditions do not produce identical distance measurements,
- why a rocket must reach an "escape velocity" before it can get into space, or
- whether varying the vinegar concentration (by diluting with water) affects flight distance.

Rocket Propulsion–It's A Gas!

Name(s): ______________________________ Period: ____________ Date: ____________

NASA needs a better rocket system for space exploration and has opened a competition for all aeronautical design companies to submit a bid for a contract to provide the fuel for the needed rockets. The contract will be awarded to the company that can create the fuel mixture that propels a rocket the farthest distance for the least cost (cost-to-distance ratio). Your "company" will design and test a new rocket fuel for the NASA competition. The rocket fuel and rocket must meet the design specifications, use only the required materials, and be cost effective. Each company will evaluate two variable components (solid fuel and liquid fuel) during the research and design phase (R&D) to determine its bid to NASA. Each company will demonstrate its best rocket fuel mixture and provide both a written report and an oral presentation that details the rocket fuel testing.

Specifications:

- All companies will start with a zero balance and will incur cost during the R&D phase.
- Each rocket fuel mixture must be tested in a minimum of five rocket launches during the R&D phase.
- A final demonstration flight (6th launch) will be conducted with the costs incurred accounted for within the data and cost analysis.

Materials for each group:

- large protractor
- 100 g baking soda (solid fuel) to be issued at a cost of $50,000 per gram used
- 300 mL white vinegar (liquid fuel) to be issued at a cost of $35,000 per mL used
- spoon or spatula
- meterstick or tape measure
- graduated cylinder
- 500 mL beaker
- rubber stoppers (#3 and #4 without holes; the "rocket")
- modeling clay (optional)
- safety goggles
- white bathroom tissue (toilet paper)
- brown lunch sack
- balance
- file folder
- eyedropper
- large box to store components
- 20 oz (591 mL) plastic bottle

Safety and Government Controls (penalties assessed by the teacher):

1. Any company violating the Occupational Safety and Health Administration (OSHA) safety rules for eye protection (goggles), noise pollution, or environmental spills (fuel spills, spraying while launching) during the testing of any rocket will be assessed a fine of $150,000 per incident.
2. Any company whose rocket goes off course during any test flight (hits ceiling, window, wall) will be fined $100,000 per incident.
3. Any company that violates another company's materials or workspace will be disqualified from the competition.
4. Any company that fails to keep a clean and orderly workspace (clean-up, return supplies, etc.) will be assessed a penalty to be determined by the government.

Company Management Policies:

1. Only fuel components supplied by the government may be used.
2. During investigation periods the liquid fuel must be kept in the beaker; between periods the liquid fuel must be stored in the bottle (tightly capped). The bottle with liquid fuel and the solid fuel (kept in a small plastic bag) must be stored in the brown paper sack labeled with company owners' names. The government shall retain control of all supplies between testing periods.
3. All company paperwork must be kept in the file folder throughout the investigation. The government shall keep the folders between testing periods.

Final Written Report:

So that an informed decision is made in the awarding of the rocket contract, NASA (your teacher) requires a written report that contains the following components:

I. Cover Sheet: Include company name and all company owners (students) plus date(s) of launches.

II. Scientific Components: Include the following written in the format outlined below:

   A. Purpose of investigation

   B. Hypothesis—(statement format)

   C. Variables—independent, dependent, and controlled

   D. Materials

   E. Procedures—(detailed and in list format)

   F. Data Table—(includes amounts and cost of solid and liquid fuel, total cost of launch, distance traveled [in metric units], fines incurred, and cost-to-distance ratio)

III. Cost Analysis: A detailed account of all expenses for fuel, fines, etc., total cost of research, and proposed selling price of rocket fuel (total cost + 10% markup for profit)

IV. Recommendations and Conclusions: Explain in paragraph format your final recommendation to NASA for the amount of solid and liquid fuel and why NASA should purchase your rocket fuel and award the contract to your company. Include in this section the best features (distance traveled, cost-to-distance ratio, safety features, etc.) of the company's rocket fuel. Be sure to include the purchase price for the rocket fuel (purchase price must cover all expenses plus 10% profit for the owners).

Summative Assessment—Oral Presentation Rubric

Name(s): ______________________________ Period: ____________ Date: ____________

Directions: Assign a score of 1, 2, or 3 points for each category as the students make their presentation. Tally the subscores and record the total score for each student in the space provided.

<table>
<tr><th colspan="2" rowspan="2">Element</th><th colspan="3">Criteria</th><th rowspan="2">Points Awarded</th></tr>
<tr><th>1 point—“emerging”</th><th>2 points—“developing”</th><th>3 points—“advanced”</th></tr>
<tr><td rowspan="3">Group Criteria</td><td>Organization</td><td>No obvious sequence of information in presentation</td><td>Information has some logical sequence, but may jump around at times</td><td>Information presented in a logical, interesting sequence</td><td></td></tr>
<tr><td>Graphics</td><td>No graphics used</td><td>Some graphics used, but they are inadequate to support presentation</td><td>Graphics relate to and enhance presentation</td><td></td></tr>
<tr><td>Mechanics</td><td>Presentation has four or more spelling/grammar errors</td><td>Presentation has two or three spelling/grammar errors</td><td>Presentation has no more than one spelling/grammar error</td><td></td></tr>
</table>

Group Subscore: ____________

<table>
<tr><td rowspan="12">Individual Criteria</td><td rowspan="4">Knowledge of Topic</td><td rowspan="4">Student does not have a grasp of the topic, cannot answer questions about subject</td><td rowspan="4">Student is somewhat uncomfortable with topic and is able to answer only rudimentary questions</td><td rowspan="4">Student is at ease with topic and can answer all questions</td><td>Student 1: ______</td></tr>
<tr><td>Student 2: ______</td></tr>
<tr><td>Student 3: ______</td></tr>
<tr><td>Student 4: ______</td></tr>
<tr><td rowspan="4">Eye Contact</td><td rowspan="4">Student reads presentation with no eye contact</td><td rowspan="4">Student occasionally uses eye contact, but reads some of presentation</td><td rowspan="4">Student maintains eye contact throughout the presentation</td><td>Student 1: ______</td></tr>
<tr><td>Student 2: ______</td></tr>
<tr><td>Student 3: ______</td></tr>
<tr><td>Student 4: ______</td></tr>
<tr><td rowspan="4">Clarity</td><td rowspan="4">Student mumbles and speaks too quietly for everyone to hear presentation</td><td rowspan="4">Student speaks clearly, but soft enough so that some people have difficulty hearing presentation</td><td rowspan="4">Student speaks clearly and loud enough so all members of the audience can hear presentation</td><td>Student 1: ______</td></tr>
<tr><td>Student 2: ______</td></tr>
<tr><td>Student 3: ______</td></tr>
<tr><td>Student 4: ______</td></tr>
</table>

Individual Subscores: Student 1 ______ Student 2 ______ Student 3 ______ Student 4 ______

TOTAL SCORE: Student 1 ____/18 Student 2 ______/18 Student 3 ______/18 Student 4 ______/18

Comments:

Adapted from Information Technology Evaluation Services, North Carolina Department of Public Instruction, 1997.

Summative Assessment—Written Lab Report Rubric (“NASA Report”)

Name(s): ______________________ Period: __________ Date: __________

Directions: Read each criterion and then assign points accordingly. Comments can be recorded in the space provided.

Section	Criteria	Points	Points Awarded
I. Cover sheet	Includes company and owners' names plus launch date(s)	5	
II. Scientific Components			
A. Purpose	Is clearly stated and accurate	3	
B. Hypothesis	Is in correct format and written correctly	3	
C. Variables	Includes independent, dependent, and controlled variables and has correctly identified each	10	
D. Materials	Is complete and in a list format	3	
E. Procedures	Gives sufficient details and in a list format	15	
F. Data Table			
(visual display)	Has title; includes data for six trials/launches; includes labels; identifies units of measurement and uses them correctly	5	
(information)	Includes amounts and costs of fuels, distance traveled, fines incurred, total cost per launch, cost-to-distance ratio	15	
III. Cost analysis			
(visual display)	Gives a detailed accounting that is logical and accurate	5	
(information)	Includes all fuel expenses, extra fuel purchases, fines, total cost of research, and proposed selling price	20	
IV. Recommendations and Conclusions	Are clearly stated in paragraph format and supported by the presented data	16	
	Total points:	**100**	

Comments:

Instructional Activities for PLAN Science

Why Are Additional Instructional Activities Included?

The set of instructional activities that begins on page 48 was developed to illustrate the link between classroom-based activities and the skills and understandings embedded in the PLAN Science Test questions. The activities are provided as examples of how classroom instruction and assessment, linked with an emphasis on reasoning, can help students practice skills and understandings they will need in the classroom and in their lives beyond the classroom. It is these skills and understandings that are represented on the PLAN Science Test.

A variety of thought-provoking activities, such as short- and long-term collaborative projects for both small and large groups, are included to help students develop and refine their skills in many types of situations.

The instructional activities that follow have a similar organizational structure as the one in the previous section. *Like the other activity, these activities were not developed to be a ready-to-use set of instructional strategies.* ACT's main purpose is to illustrate how the skills and understandings embedded in the PLAN Science Test questions can be incorporated into classroom activities.

For the purpose of this part of the guide, we have tried to paint a picture of the ways in which the activities could work in the classroom. We left room for you to envision how the activities might best work for you and your students. We recognize that as you determine how best to serve your students, you take into consideration your teaching style as well as the academic needs of your students; state, district, and school standards; and available curricular materials.

The instructional activities are not intended to drill students in skills measured by the PLAN Science Test. It is never desirable for test scores or test content to become the sole focus of classroom instruction. However, considered with information from a variety of other sources, the results of standardized tests can help you identify areas of strength and weakness. The activities that follow are examples of sound educational practices and imaginative, integrated learning experiences. As part of a carefully designed instructional program, these activities may result in improved performance on the PLAN Science Test—not because they show how to drill students in specific, isolated skills but because they encourage thinking and integrated learning. These activities can help because they encourage the kind of thinking processes and strategies the PLAN Science Test requires.

Guiding Principles

- "When carefully guided by teachers to ensure full participation by all, interactions among individuals and groups in the classroom can be vital in deepening the understanding of scientific concepts and the nature of scientific endeavors." (National Research Council [NRC], 1996, p. 32)
- By supporting student ideas and questions and by encouraging students to pursue them, teachers create the opportunity for students to take responsibility for their own learning. (NRC, 1996)
- "A teacher who engages in inquiry with students models the skills needed for inquiry." (NRC, 1996, p. 37)

Local Water Quality

College Readiness Standards

- Select two or more pieces of data from a simple data presentation
- Identify basic features of a table, graph, or diagram (e.g., headings, units of measurement, axis labels)
- Compare or combine data from a simple data presentation (e.g., order or sum data from a table)
- Translate information into a table, graph, or diagram
- Extrapolate from data points in a table or graph
- Determine how the value of one variable changes as the value of another variable changes in a simple data presentation

Description of the Instructional Activity

Collaboration with local environmental agencies can be used to help students learn to manipulate and make inferences from raw data. A local environmental agency (such as your state's Department of Natural Resources, the Army Corps of Engineers, a local water utility, etc.) could be contacted to ask if it is possible to obtain data on a local stream, lake, bay, etc. The Internet is another good place to search for this type of data. The data could be flow rates, temperatures, turbidity, pH, nitrate levels, plant and animal life, etc. Ideally, a field trip could be arranged to the local agency, or environmental professionals could visit the classroom to demonstrate and/or explain how some of the data was obtained and how it is used.

Students can then work individually or in groups (depending on the volume of data) to translate the data into different forms. If the students have not had a lot of experience in graphing, this would be a good opportunity to acquaint them with the many methods available for data presentation. Throughout the activity, students can be asked guiding questions.

When all of the data is plotted, students can share their work. They can discuss the basic features of their representations (e.g., headings, units of measurement, axis labels). They can identify specific data points from the raw data or from the graphical representations and discuss measurement issues related to specific data points, such as precision and variability. They can identify the range of values associated with a specified set of data. They can identify changes within data sets and describe how the data changed with respect to an independent variable, such as temperature and time. They can identify relationships in the data, comparing graphs in order to make inferences and draw conclusions (e.g., how flow rate affects the presence of certain types of fish, insects, and plants, or how temperature affects the levels of dissolved oxygen). Students should be encouraged to bring in other resources when formulating their conclusions, such as information from the library, Internet, and local professionals.

Suggestions for Assessment

Performance Assessment—Students can prepare presentation-size charts and graphs to share with the class, and they can be encouraged to utilize software that they (or the school) have access to for plotting the data. Students can be assessed on the quality and utility of their presentations. Students can then prepare reports (with embedded graphics), stating what they have learned about the water system they studied. The assessment of this activity could include graphing abilities, but also understanding of the scientific concepts underlying the data. Students can also be asked questions that involve extrapolation and interpolation of their data. The criteria for assessing the quality of student reports could be shared in advance, so that students can better anticipate and meet expectations.

Ideas for Progress

- Design and carry out additional scientific inquiries to answer specific questions
- Formulate hypotheses, predictions, or conclusions by comparing and contrasting several different sets of data from different experiments
- Evaluate the merits of a conclusion based on the analysis of several sets of data

Suggested Strategies/Activities

If the data revealed troublesome issues with the water system studied, students could research the issue, assessing the future impact of the issue and making recommendations for improving water quality. If equipment is available, students could also conduct their own study of a local water system. There are also many resources on the Internet for investigations of water systems. Students could design their own website detailing their investigation, possibly linking up with other schools doing similar projects.

Guiding Principles

- "Well-conceived school laboratory experiences . . . provide opportunities for students to become familiar with the phenomena that the science concepts being studied try to account for." (American Association for the Advancement of Science [AAAS], 1993, p. 9)
- "Working collaboratively with others not only enhances the understanding of science, it also fosters the practice of many of the skills, attitudes, and values that characterize science." (NRC, 1996, p. 50)

Chemical Weathering

College Readiness Standards

- Determine how the value of one variable changes as the value of another variable changes in a simple data presentation
- Understand the methods and tools used in a simple experiment
- Identify a control in an experiment
- Identify and/or use a simple (e.g., linear) mathematical relationship between data
- Understand a simple experimental design
- Identify an alternate method for testing a hypothesis
- Select a data presentation or a model that supports or contradicts a hypothesis, prediction, or conclusion

Description of the Instructional Activity

Acid rain is known to affect rivers, lakes, and forests, but it can also affect rocks, statues, and buildings. By the process of *chemical weathering,* a statue can literally "lose face." Many statues have had their distinguishing features slowly eaten away by the more acidic rain that often exists near highly industrialized areas. Marble and other building materials dissolve in acids, which makes them susceptible to the heightened acidity of acid rain. In the following activity, groups of students can study different factors that affect the rate at which chemical weathering occurs.

For this activity, students can use chalk to represent marble and vinegar to represent acid rain (Bernstein et al., 1991). Chalk is chemically identical to marble ($CaCO_3$) but is not as highly compacted, so it is even more vulnerable to acid attack than marble. Using chalk will allow students to simulate processes in the laboratory that typically occur over many years. Vinegar contains acetic acid and is more acidic than most acid rain, but this can be changed by diluting vinegar with water. Groups of students will use these materials to study two different factors affecting chemical weathering rate, acidity (pH) and surface area. The following materials will be needed: chalk, vinegar, pH paper, water, and beakers (250 mL).

Pour 100 mL of water into one beaker, 100 mL of vinegar into another beaker, and combine 80 mL of water with 20 mL of vinegar in a third beaker. Have students test the pH of each liquid with pH paper, writing the results in their lab book or journal. Place a piece of chalk in each beaker at approximately the same time. When chalk reacts with vinegar, bubbles of CO_2 gas form. Observing the amount of bubbling that occurs in the reaction will indicate how fast the reaction is occurring. Have students observe the chalk over the next 10 minutes, recording their observations. Students can also recheck the pH of the solution at regular intervals.

For the next part of the activity, each group of students should make a solution of 1 part vinegar and 4 parts water. Pour 100 mL of the vinegar-and-water solution into each of four beakers. Use four pieces of chalk; keep one piece whole, break one piece in half, break another piece into four pieces, and crush a fourth piece. Different group members should simultaneously add the whole piece of chalk to one beaker, the two half pieces to another beaker, the quartered pieces to the third beaker, and the crushed piece to the last beaker. Over the next 10 minutes, students should observe and note what happens to the chalk in each beaker. Students should try to estimate the relative reaction rates in each beaker by noting how vigorous each reaction is and how quickly the chalk dissolves.

Linking Instruction and Assessment

Strands: *Interpretation of Data; Scientific Investigation; Evaluation of Models, Inferences, and Experimental Results*

Suggestions for Assessment

Multiple-Choice Questions—Prior to the activity, students could be given a multiple-choice assessment to determine their knowledge of relevant terms and concepts. Asking them to include reasons for their answer choices could provide further insight into student misconceptions, which may be addressed with additional instruction and guidance.

Paper-and-Pencil Tasks—After students have completed the first part of the activity, they can be asked questions like:

- *What hypothesis was tested by the experiment?*
- *Why were chalk and vinegar used in the experiments, and how does each relate to marble and acid rain?*
- *How does the concentration of vinegar in water affect a solution's pH?*
- *What is the relationship between the acidity of a liquid and the rate at which it dissolves chalk?*
- *Did the pH change during the 10 minutes the chalk was in each liquid? Why or why not?*
- *What is the relationship between the concentration of an acid solution and its acidity?*
- *How does this experiment relate to acid rain and chemical weathering?*
- *Which of the preparations served as a control?*

Performance Assessment—Students can compare and combine the data from both parts of the activity to relate reaction rates to concentration and surface area. The students can graph their results on a relative scale, which provides a good context for the discussion of relative scaling. After evaluating all of the data, students can be asked questions such as:

- *What is the relationship between surface area and the rate at which the chalk dissolved?*
- *Why does the surface area of the chalk affect the reaction rate?*
- *What is the relationship between the size of the chalk pieces and the reaction rate?*
- *What are additional experiments that could be performed to test this hypothesis?*
- *Why does rain that is more acidic than normal rain cause marble buildings and statues to erode?*
- *If you had two marble blocks of the same size, but one had intricate engraving on its surface, which of the blocks would be more susceptible to chemical weathering, and why?*
- *What data from the experiment supports your hypothesis about the susceptibility of the two marble blocks to chemical weathering?*

Ideas for Progress

- Formulate hypotheses, predictions, or conclusions based on the results of an experiment
- Perform experiments that require more than one step
- Carry out scientific investigations in which the importance of accuracy and precision is stressed

Suggested Strategies/Activities

This activity could be expanded by performing tests on actual building materials, such as marble, granite, and concrete (tiles could be obtained at a local hardware store). The rates at which these materials dissolve could be measured more quantitatively and over a longer time period than was done for chalk. Dilute solutions of the actual acids that typically compose acid rain (nitric acid and sulfuric acid) could be tested to see which one corrodes marble at a faster rate. The effects of temperature could be studied. Concentration and surface area could be more fully and quantitatively explored than was done in the preceding activities. Students could also decoratively carve designs into pieces of chalk. Then, these "statues" could be dipped in vinegar-and-water solutions and students could see how chemical weathering affected the details in their artwork.

Guiding Principles

- "Preparing students to become effective problem solvers, alone and in concert with others, is a major purpose of schooling." (AAAS, 1993, p. 282)
- "Teaching for understanding requires responsiveness to students, so activities and strategies are continuously adapted and refined to address topics arising from student inquiries and experiences, as well as school, community, and national events." (NRC, 1996, p. 30)
- "When secondary sources of scientific knowledge are used [in the classroom], students need to be made aware of the processes by which the knowledge presented in these sources was acquired and to understand that the sources are authoritative and accepted within the scientific community." (NRC, 1996, p. 31)

Paper or Plastic?

College Readiness Standards

- Find basic information in a brief body of text
- Analyze given information when presented with new, simple information
- Identify strengths and weaknesses in one or more models
- Identify similarities and differences between models
- Identify key issues or assumptions in a model
- Determine whether new information supports or weakens a model, and why
- Select a complex hypothesis, prediction, or conclusion that is supported by a data presentation or model
- Use new information to make a prediction based on a model

Description of the Instructional Activity

A question we often face at the local supermarket is—*Paper or plastic?* Many people choose their grocery bag based on preference and functionality, without thinking of the ramifications of their choice. Many others would like to make an informed decision based on many factors, such as use of natural resources, pollution, waste disposal, cost to the store, etc., but do not have this data. In this activity, students can try to consider all of the issues involved, including the science and technology involved in production and disposal, the environmental impact, and economic and political factors.

The class can be divided into three groups. One group can be the investigative team for plastic bags and another group for paper bags. The third group can act as an independent research team that will also serve as a jury for final recommendations.

A certain amount of time can be allotted so that each group can **thoroughly** investigate as many issues as possible related to the topic. The plastic bag group will focus on the virtues of plastic, and the paper bag group will focus on the virtues of paper, but each will need to know the weaknesses in their case and develop lines of reasoning to lessen their impact. The independent team will need to gather data on both sides of the issue so they can intelligently consider the information they receive. Following is a list of factors (Schwarz et al., 1994) students may consider in building their cases, but students should be encouraged to expand this list and dig deeper into the issue:

- Availability and cost of natural resources for production, including the water, electricity, etc. used during manufacturing, transportation, and disposal
- Environmental impact of manufacturing, transportation, and disposal
- Economic issues (cost of production and transportation, store costs)
- Storage issues (size and weight)
- Consumer issues (preference, recycling, costs)

Linking Instruction and Assessment

Strands: *Interpretation of Data; Evaluation of Models, Inferences, and Experimental Results*

One possibility for generating ideas for investigation is to have students make concept maps related to the task. Students can visit libraries, consult newspaper or magazine articles, search the Internet, and use other related sources. They can interview grocers, waste management workers, city administrators, and college professors. Students from each team can gather evidence into a comprehensive report or portfolio, including charts and graphs.

The investigation can culminate in a mock public hearing. Each team will present its case to the independent team. Throughout the hearing, the independent team can discuss the validity of the data that is presented. They can identify assumptions made by both sides. They can identify the strengths and weaknesses in the two cases. They can introduce new information that they discovered during their research and ask each side how the information impacts the two positions. They can also combine the strongest parts of the two presentations in order to make recommendations to the public at the conclusion of the hearing. Following the recommendations, all of the students can discuss the similarities and the differences between the two viewpoints. They can identify key issues to help them determine situations in which paper may be preferable and situations in which plastic may preferable.

Suggestions for Assessment

Scoring Rubric—The reports could be assessed on their depth of investigation and how the report demonstrates the students' ability to interpret the scientific and technological information they have included. Prior to the hearing, the teacher can share with students the criteria that will be used for assessing their performances. This could be in the form of rubrics, containing elements such as accuracy of information presented, the strength and logic of their arguments, public presentation, persuasiveness, preparedness, participation, diplomacy, etc. Each group can also examine the reports generated by the other groups. This would provide the possibility for each student to do a peer evaluation of each group's work.

Ideas for Progress

- Compare and contrast two different models about a scientific phenomenon
- Relate scientific information contained in written text to numerical data
- Determine alternate methods of testing a hypothesis

Suggested Strategies/Activities

Students could design and carry out experiments testing the usefulness and quality of different types of grocery bags. This could include tests for weight capacity, volume, the ability to withstand sharp objects, the strength when wet, and biodegradability. Consumer preference could also be evaluated with surveys.

Guiding Principles

- "Because assessment information is a powerful tool for monitoring the development of student understanding, modifying activities, and promoting student self-reflection, the effective teacher of science carefully selects and uses assessment tasks that are also good learning experiences." (NRC, 1996, p. 38)
- "Students develop an understanding of the natural world when they are actively engaged in scientific inquiry—alone and with others." (NRC, 1996, p. 29)
- "Teachers who exhibit enthusiasm and interest and who speak to the power and beauty of scientific understanding instill in their students some of those same attitudes toward science." (NRC, 1996, p. 37)

Salt Pollution

College Readiness Standards

- Identify a control in an experiment
- Determine how the value of one variable changes as the value of another variable changes in a complex data presentation
- Compare or combine data from two or more simple data presentations (e.g., categorize data from a table using a scale from another table)
- Understand the methods and tools used in a moderately complex experiment
- Understand the methods and tools used in a complex experiment
- Understand a complex experimental design
- Select a simple hypothesis, prediction, or conclusion that is supported by a data presentation or a model

Description of the Instructional Activity

Why don't the farmers living near oceans use this vast source of water on their crops? Salts are commonly used on the roads in areas that have ice and snow. When it rains, the salts dissolve and seep into the surrounding soils. How does this affect the nearby plant life? In this activity, students can study the effects of salt on the growth of bean plants (Avakian et al., 1996).

To do this activity, several young bean plants, all of approximately the same age, will be needed (other plants, such as grass, pea, or corn could also be used). Doing an activity on the germination of beans prior to this activity would provide not only an excellent context for this activity, but also the necessary plants! This activity can also provide an excellent setting for research and a discussion about scientific investigation (i.e., hypotheses, controls, independent and dependent variables, and experimental trials). For example, students can perform research to determine the conditions that promote plant growth. They can investigate the types of soils that should be used, as well as fertilizers that can be added to the soils to promote growth. They can determine the amount of water and sunlight that the plants will require. They can then make predictions about the effect of salt on plant growth. Students can then test their hypotheses. They can devise experimental and control groups, and then predict how growth will vary in response to the conditions used in each trial. The following experimental procedures could be used as a guide for helping students design their own experiments.

Most land plants (including beans) will not tolerate the salt concentration of ocean water. Since seawater is about 3.5% salts, solutions of different concentrations can be made ranging from 0% to 3.5% of a salt ($NaCl$ or $CaCl_2$ could be used). Each group of students should make initial measurements and observations of the plants, ensuring that they are placed in an area where they receive the same amount of light. Students can then label the plants in pairs as A1, A2, B1, B2, C1, C2, etc. Students can then develop a regular watering schedule in which A1 and A2 will receive water, B1 and B2 will receive 0.5% salt water, C1 and C2 will receive 1.0% salt water, and so forth. They can make observations and measurements of the plants at regular intervals. After the students have collected enough data, they can plot their data. They can then use their graphs and observations to draw conclusions. Students can share these conclusions with the class, comparing their results and how they chose to organize and display their data, and explaining how they arrived at their conclusions.

Linking Instruction and Assessment

Strands: *Interpretation of Data; Scientific Investigation; Evaluation of Models, Inferences, and Experimental Results*

Suggestions for Assessment

Multiple-Choice Questions—Prior to the activity, students could be given a multiple-choice assessment to determine their knowledge of relevant terms and concepts. Asking them to include reasons for their answer choices could provide further insight into student misconceptions, which may be addressed with additional instruction and guidance.

Paper-and-Pencil Tasks—Throughout the activity, students could be asked questions such as:

- *Why was it necessary to place the plants in an area where they would all receive the same amount of light?*
- *Which treatment in the experiment served as a control?*
- *Why were pairs of plants given the same treatment? Would it have been better to have used more plants for each treatment?*
- *Why is salt water harmful to plants?*
- *What salt concentration can be tolerated by bean plants?*
- *What is the relationship between the rate at which a plant grows and the concentration of salts in the solution used to water the plant? Were there other effects on plant growth (e.g., branching)?*
- *How could the results of your experiment be used to better inform the public about salt pollution?*

Performance Assessment—Students could be assessed on the quality of their experimental design, their data collecting and handling techniques, and the presentation and justification of their hypotheses and conclusions.

Ideas for Progress

- Perform experiments that require more than one step
- Consider how changing an experimental procedure will affect the results of their scientific investigations

Suggested Strategies/Activities

The previous activity only evaluated the effects of concentration for one type of plant and one salt. Students could try multidimensional experiments, varying both plant type and salt concentration. Similarly, students could examine how different types of salts (NaCl, $CaCl_2$, KCl, etc.) affect plant growth. Students could also examine the effects of salt concentration on seed germination.

Guiding Principles

- "At all stages of inquiry, teachers guide, focus, challenge, and encourage student learning." (NRC, 1996, p. 33)
- "Teachers of science [should] orchestrate their class so that all students have equal opportunities to participate in learning activities." (NRC, 1996, p. 37)
- "Before graduating from high school, students working individually or in teams should design and carry out at least one major investigation. They should frame the question, design the approach, estimate the time and costs involved, calibrate the instruments, conduct trial runs, write a report, and finally, respond to criticism." (AAAS, 1993, p. 9)

Weather Watchers

College Readiness Standards

- Select a single piece of data (numerical or nonnumerical) from a simple data presentation (e.g., a table or graph with two or three variables; a food web diagram)
- Understand basic scientific terminology
- Translate information into a table, graph, or diagram
- Select data from a complex data presentation (e.g., a table or graph with more than three variables; a phase diagram)
- Compare or combine data from a complex data presentation
- Interpolate between data points in a table or graph
- Select a simple hypothesis, prediction, or conclusion that is supported by a data presentation or a model
- Identify and/or use a complex (e.g., nonlinear) mathematical relationship between data

Description of the Instructional Activity

Should we have the picnic today or tomorrow? Should we call off the game or wait it out? We've all faced these types of questions concerning the weather, which is why humans have tried to make predictions about the weather throughout history. Although computers and sophisticated radar have improved weather forecasts, much of the data is gathered with instruments that are relatively simple and can be built at home. Many books (for example, Avakian et al., 1996) provide simple instructions on how to build weather vanes, rain gauges, anemometers, barometers, psychrometers, and others. These instruments can be used to turn a classroom into a working weather station.

The class can be divided into two groups, each with its own instrument(s) to build. One opportunity for students would be to arrange a field trip to a weather station (at a local television station or governmental agency). Students can see how the "real" versions of their instruments look and work. They can speak with a meteorologist about his or her daily duties and the education and training meteorologists need. If this is not possible, students can consult the library and the Internet to learn about the instrument(s) they will build. During their research, students can keep a log of the information they discover. They can note the vocabulary used to describe the instrumentation and physical properties that the instruments measure. They can consult reference works to ensure that they fully understand this terminology. They can then use the procedures that they find in their research or use their own ideas to develop a plan for creating each instrument. They can then build each instrument. Students should thoroughly test and modify their instruments, keeping a careful log of scale drawings and test data showing the progression of this phase of activity.

Over the course of several days (or weeks) each group can monitor conditions with their instruments at regular intervals, exchanging their data so that all of the data can be combined and comparisons can be made using this complex data set. If a school already has access to weather instruments, students can also collect data with the "real" instruments to gauge the performance of their instruments. Students can record their data in tabular form. They can then create graphical representations of the data (e.g., line or bar graphs). They could also use computer software programs, such as spreadsheets, to plot the data they have collected. Students can then further analyze these representations. For example, they can extrapolate beyond the data ranges or they can interpolate between data points to predict values that were not collected. Students can develop mathematical models to describe the relationships that exist between different variables.

Along with the data collected with their instrumentation, students should also record temperature and the observable weather conditions at the time of measurement (cloudiness, precipitation, etc.). Groups should then examine the relationship between the measurements and these conditions and try their hand at forecasting the weather.

Suggestions for Assessment

Portfolio—The activity could culminate in a portfolio containing drawings, graphs, and charts displaying the work the students put into building their instrument, the data they gathered, and their interpretations and conclusions. Teachers could share in advance the criteria they will use for evaluating their portfolios.

Ideas for Progress

- Create basic tables and graphs from sets of scientific data
- Describe trends and relationships in data displayed in simple tables and graphs
- Evaluate whether the data produced by an experiment adequately support a given conclusion
- Seek out new information that enhances or challenges their existing knowledge

Suggested Strategies/Activities

A fun activity at the end of this project is to have each group orchestrate and perform a mock weather broadcast. In their broadcasts, they can illustrate the results of their study with maps and charts and make predictions about the upcoming week's weather based on these results. These broadcasts could be videotaped so that students could better evaluate their public presentation skills. Students could also study the meteorology and physics behind storms, tornadoes, and lightning. Not only do students typically find storms fascinating, but topics such as the electrical and magnetic properties of storms and the behavior of gases during storms could be addressed in this context.

Putting the Pieces Together

ACT developed this guide to show the link between the PLAN Science Test results and daily classroom work. The guide serves as a resource for teachers, curriculum coordinators, and counselors by explaining what the College Readiness Standards say about students' academic progress.

The guide explains how the test questions on the PLAN Science Test are related to the College Readiness Standards and describes what kinds of reasoning skills are measured. The sample instructional activities and classroom assessments suggest some approaches to take to help students develop and apply their reasoning skills.

Where Do We Go From Here?

ACT recognizes that teachers are the essential link between instruction and assessment. We are committed to providing you with assistance as you continue your efforts to provide quality instruction.

ACT is always looking for ways to improve its services. We welcome your comments and questions. Please send them to:

College Readiness Standards Information Services
Elementary and Secondary School Programs (32)
ACT
P.O. Box 168
Iowa City, IA 52243-0168

"A mind, stretched to a new idea, never goes back to its original dimensions."

— Oliver Wendell Holmes

What Other ACT Products and Services Are Available?

In addition to the College Readiness Standards Information Services, ACT offers many products and services that support school counselors, students and their parents, and others. Here are some of these additional resources:

ACT's Website—**www.act.org** contains a host of information and resources for parents, teachers, and others. Students can visit **www.planstudent.org**, which is designed to aid students as they prepare for their next level of learning.

The ACT—a guidance, placement, and admissions program that helps students prepare for the transition to postsecondary education while providing a measure of high school outcomes for college-bound students.

EXPLORE—an eighth- and ninth-grade assessment program designed to stimulate career explorations and facilitate high school planning.

WorkKeys®—a system linking workplace skill areas to instructional support and specific requirements of occupations.

ACT Online Prep™—an online test preparation program that provides students with real ACT tests and an interactive learning experience.

The Real ACT Prep Guide—the official print guide to the ACT, containing three practice ACTs.

DISCOVER®—a computer-based career planning system that helps users assess their interests, abilities, experiences, and values, and provides instant results for use in investigating educational and occupational options.

Bibliography

This bibliography is divided into three sections. The first section lists the sources used in describing the PLAN Program, the College Readiness Standards for the PLAN Science Test, and ACT's philosophy regarding educational testing. The second section, which lists the sources used to develop the instructional activities and assessments, provides suggestions for further reading in the areas of thinking and reasoning, learning theory, and best practice. The third section provides a list of resources suggested by classroom teachers.

(Please note that in 1996 the corporate name "The American College Testing Program" was changed to "ACT.")

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(All retrieved by ACT June 3, 2005.)

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http://www.enc.org/topics/inquiry

Educational REALMS: Resources for Engaging Active Learners in Math and Science.
http://www.stemworks.org/realmshomepage.html

The Franklin Institute Science Museum.
Learn—The Franklin Institute Online.
http://sln.fi.edu/learn.html

The Gateway to Educational Materials.
http://www.thegateway.org

National Science Teachers Association.
http://www.nsta.org

Northwest Regional Educational Laboratory.
Mathematics and Science Education Center: Science Inquiry Model.
http://www.nwrel.org/msec/science_inq/index.html

Earth/Space Science Research Summaries passage for sample test questions found on pages 14 and 17

Lead (Pb) is a toxic contaminant put into the air by a variety of human activities. Airborne Pb particles can be carried to the ground by rainfall. The following studies were done to find out what happens to the Pb after it reaches the ground. The study site was a forested area in the northeastern U.S.

Study 1

Scientists wanted to learn whether the Pb stayed in the surface soil layer or whether the Pb was carried down into the *subsoil* (soil layer directly below the surface soil). Pb in the subsoil is more likely to move into the groundwater supply and then into groundwater-fed streams than Pb in the surface soil. Thirty samples each of rainwater, surface soil, subsoil, groundwater, and stream water were taken from the study site. The samples were analyzed for their Pb concentration, reported in parts per billion (ppb). The average Pb concentrations of the samples are given in Table 1.

Table 1

Sample	Average Pb concentration (ppb)
Rainwater	0.6
Surface soil	5.4
Subsoil	0.4
Groundwater	0.05
Stream water	0.003

Study 2

To determine if Pb concentration in groundwater and stream water varied with elevation, samples of stream water and groundwater were collected at a number of locations at different elevations between 400 m and 750 m. The averaged results of the Pb analysis of groundwater and stream water samples from those various elevations are shown in Figure 1.

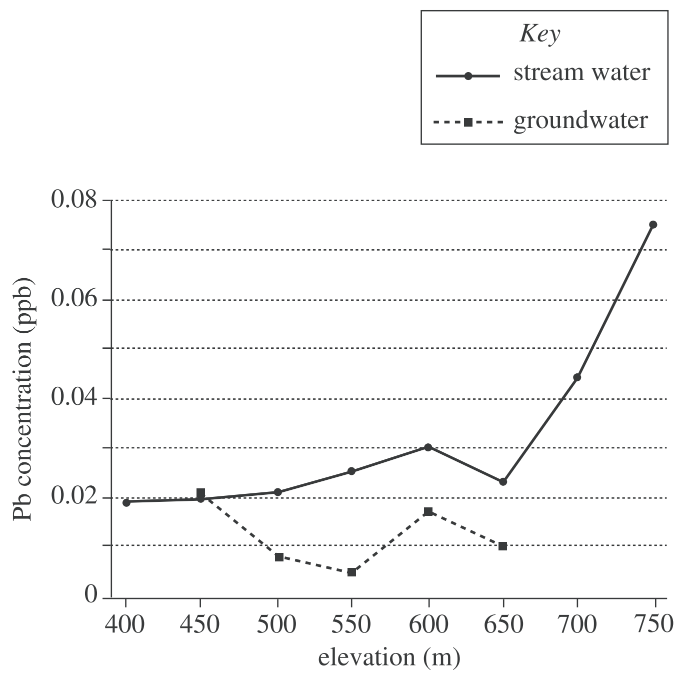


Figure 1

Study 3

To study how Pb concentration in streams and groundwater varied over time, samples of stream water and groundwater from the study site were collected and analyzed for Pb concentration. The results, averaged for each month from May through November, are shown in Figure 2.

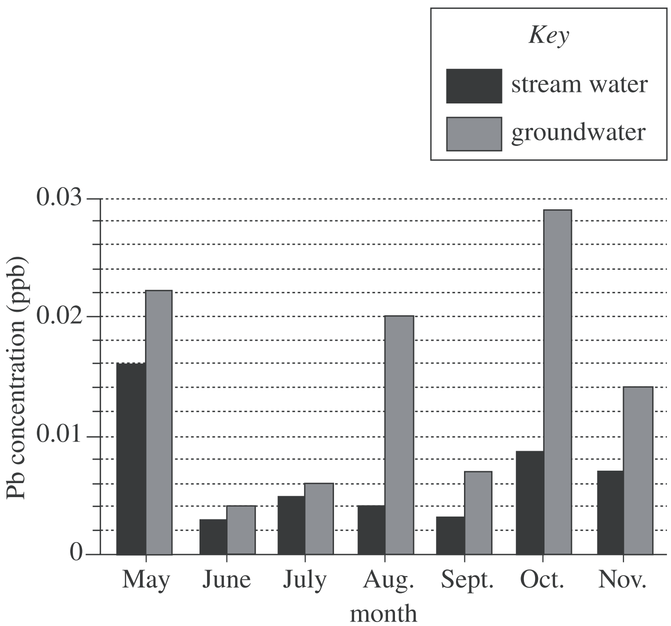


Figure 2

Figures and table adapted from Edward Wang, F. Herbert Bormann, and Gaboury Benoit, "Evidence of Complete Retention of Atmospheric Lead in the Soils of Northern Hardwood Forested Ecosystems." ©1995 by the American Chemical Society.

Earth/Space Science Data Representation passage for sample test question found on page 14

Sunspots are areas on the Sun's surface that appear dark because the gases in those areas are cooler than the surrounding gases. Figures 1 and 2 show the variations in the average number of visible sunspots for 2 different time periods, including *sunspot maxima* (when the number of sunspots peak).

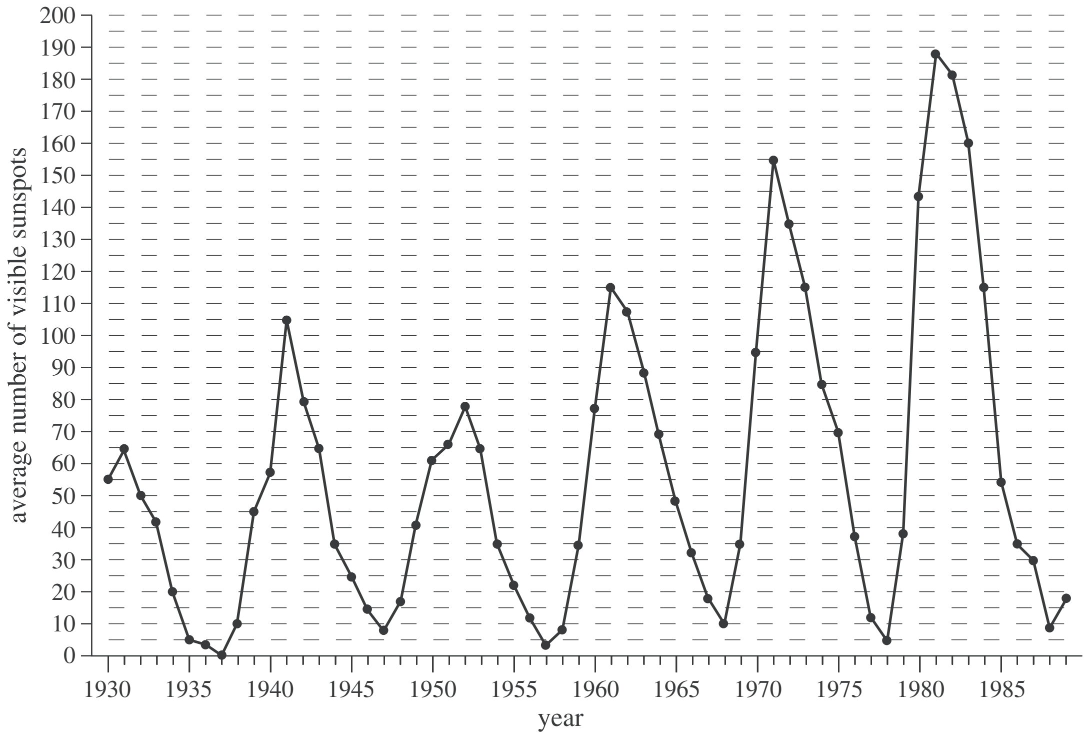


Figure 1

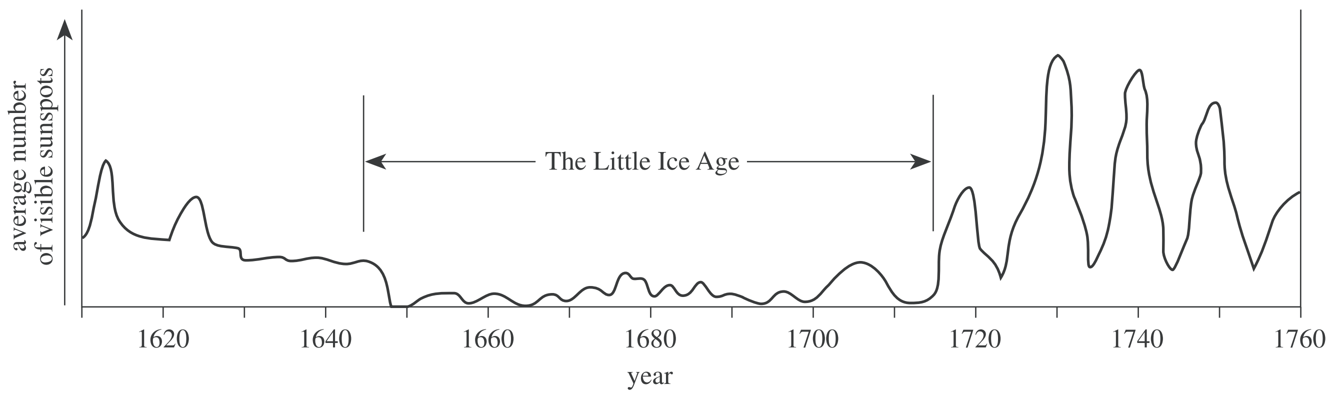


Figure 2

Table 1 shows the relationship between sunspot diameter in kilometers (km) and *solar flares* (violent eruptions that occur near sunspots and can send strong X rays and charged particles toward Earth).

Table 1

Sunspot diameter (km)	Average number of associated solar flares per day
15,000	100
12,000	85
9,000	62
7,000	48
3,000	27

Physics Research Summaries passage for sample test questions found on pages 14 and 18

A student investigates the factors that influence the *coefficient of restitution* (COR) between a ball and the floor when the ball is dropped onto a flat surface. The COR is the ratio of how high the ball bounces compared to the height from which it was dropped. The larger the COR, the higher the ball will bounce.

Experiment 1

An *elastic* ball is able to return to its original shape after being compressed or deformed and has a high COR. The student determined the COR of several different elastic balls by standing next to an upright 2 m measuring stick and dropping the balls individually from the same height of 2 m onto a hardwood floor. Each drop was recorded with a video camera and the replay of the tape was used to determine the height of the bounce. The data are shown in Table 1.

Table 1

Type of ball	Height bounced (m)	COR
"Super Ball"	1.57	0.89
Volleyball	1.10	0.74
Tennis (well-worn)	0.99	0.71
Tennis (new)	0.88	0.67
Softball	0.20	0.31

Experiment 2

The student dropped a volleyball from a height of 2 m on different floor surfaces. The same video camera recorded the bounces. The data are shown in Table 2.

Table 2

Type of surface	Height bounced (m)	COR
Wood	1.14	0.76
Concrete	1.09	0.74
Gravel	0.73	0.61
Grass	0.37	0.43

Tables adapted from James G. Hay, *The Biomechanics of Sports Techniques.*

Experiment 3

The temperature of four different balls was varied by cooling them in a freezer for 1 hour, keeping them at room temperature for 1 hour, and heating them for 15 minutes at 225°C. At each of the three resulting temperatures, the same procedure was repeated as in Experiment 1. The height bounced and COR slightly increased for both a baseball and a "Super Ball" as their temperatures increased. The height bounced and COR increased even more for a solid rubber ball and a golf ball as their temperatures increased.

Chemistry Data Representation passage for sample test questions found on pages 15 and 16

The following tables show how temperature and pressure (in atmospheres, atm) affect the solubility of several different solid and gaseous substances in water. Solubility can be defined as the maximum number of grams (g) of a substance that can dissolve in 100 g of water.

Table 1

	Solubility (g/100 g water)			
Solid substances	25°C 1 atm	25°C 2 atm	50°C 1 atm	100°C 1 atm
Sodium chloride	36	36	37	40
Potassium nitrate	37	37	85	246
Sodium nitrate	92	92	114	180
Sucrose	210	210	260	487

Table 2

	Solubility (g/100 g water)			
Gaseous substances	25°C 1 atm	25°C 2 atm	50°C 1 atm	100°C 1 atm
Carbon dioxide	0.14	0.28	0.0761	0
Oxygen	0.0039	0.0078	0.0027	0
Nitrogen	0.0018	0.0036	0.0012	0
Hydrogen	0.00015	0.00030	0.00013	0

Chemistry Research Summaries passage for sample test question found on page 16

Fluoride ion (F^-) is used in toothpaste to make teeth more resistant to acids produced by bacteria in the mouth. Like tooth enamel, eggshells react with acid. When eggshells react with hydrochloric acid (HCl), carbon dioxide (CO_2) gas is produced. The following experiments were done to study the effect of F^- on the acid resistance of eggshells.

Experiment 1

A 0.50 g eggshell sample was soaked in a 1.0% solution of F^- in distilled water for 40 min, rinsed with distilled H_2O, dried, and then placed in 4.0% HCl solution. The time required to collect 20 milliliters (mL) of CO_2 at atmospheric pressure was determined. The procedure was repeated by soaking 0.50 g eggshell samples in solutions of different F^- concentration and in distilled H_2O (see Table 1).

Table 1

F^- concentration (%)	CO_2 collection time (sec)
0	30
1.0	40
2.0	53
3.0	68
4.0	88
5.0	88
6.0	88

Experiment 2

Chloride ion (Cl^-) has chemical properties similar to F^-. Solutions of different Cl^- concentration were tested using the procedure in Experiment 1 (see Table 2).

Table 2

Cl^- concentration (%)	CO_2 collection time (sec)
1.0	33
2.0	34
3.0	35
4.0	35
5.0	35

Experiment 3

Eggshell samples of 0.50 g were each soaked for different times in a 4.0% F^- solution or in distilled H_2O. The samples were then rinsed, dried, and placed in either a 4.0% or 2.0% HCl solution. Collection times were determined as in Experiment 1 and the data were recorded in Table 3.

Table 3

Soak time (min)	CO_2 collection time (sec)			
	F^- soak		H_2O soak	
	4.0% HCl	2.0% HCl	4.0% HCl	2.0% HCl
10	40	80	30	60
20	53	106	30	60
30	68	136	30	60
40	88	176	30	60
50	88	176	30	60

Physics Data Representation passage for sample test question found on page 16

Kinetic energy is energy of motion. *Potential energy* is stored energy that can be turned into another form of energy, such as kinetic energy or heat. *Total mechanical energy* equals kinetic energy plus potential energy.

Suppose that a 1.0 kg mass, Sphere A, fell to the surface of Earth; an identical mass, Sphere B, fell to the surface of the Moon. A science class calculated the altitude, speed, potential energy, kinetic energy, and total mechanical energy as a function of the elapsed time after the spheres' release. Table 1 contains values for Sphere A; Table 2 contains values for Sphere B.

Table 1: Sphere A

Elapsed time (sec)	Altitude above Earth (m)	Speed (m/sec)	Potential energy (J)*	Kinetic energy (J)	Total mechanical energy (J)
0	100.0	0.00	980	0	980
1	97.9	3.86	959	7	966
2	92.8	6.19	909	19	928
3	85.8	7.61	841	29	870
4	77.7	8.47	761	35	796

*Note: J = joules, a unit of energy or heat.

Table 2: Sphere B

Elapsed time (sec)	Altitude above the Moon (m)	Speed (m/sec)	Potential energy (J)	Kinetic energy (J)	Total mechanical energy (J)
0	100.0	0.00	164	0	164
1	99.2	1.63	162	2	164
2	96.7	3.27	158	6	164
3	92.6	4.90	152	12	164
4	86.9	6.54	142	22	164

Physics Data Representation passage for sample test question found on page 16

As Earth and Mars move in their orbits around the Sun, Mars's *angular size* (the angle that measures how big Mars appears when observed from Earth—see Figure 1) and *apparent magnitude* (how bright Mars looks when observed from Earth) both change.

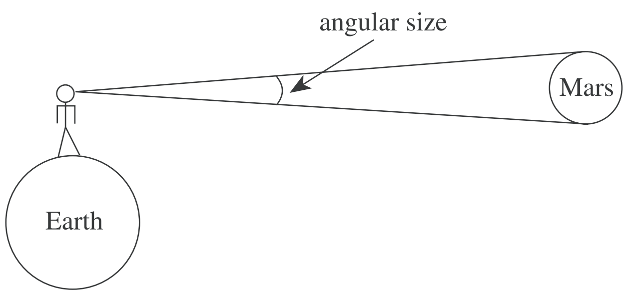


Figure 1

Figure 2 shows Earth's and Mars's positions during a given time interval. When Earth is at Position A, Mars is at Position A1; when Earth is at Position B, Mars is at Position B1; and so on. As Earth's and Mars's positions change, both Mars's angular size and apparent magnitude vary, as shown in Figures 3 and 4, respectively.

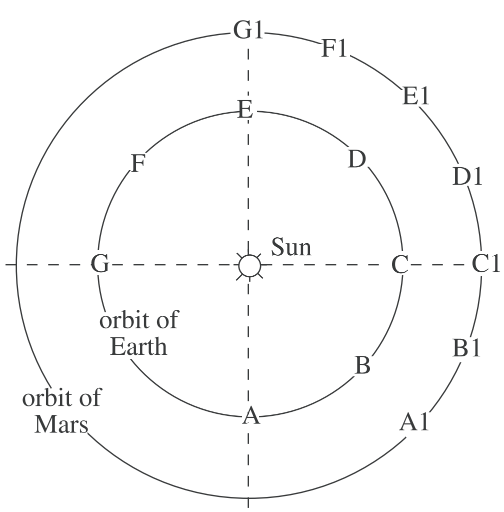
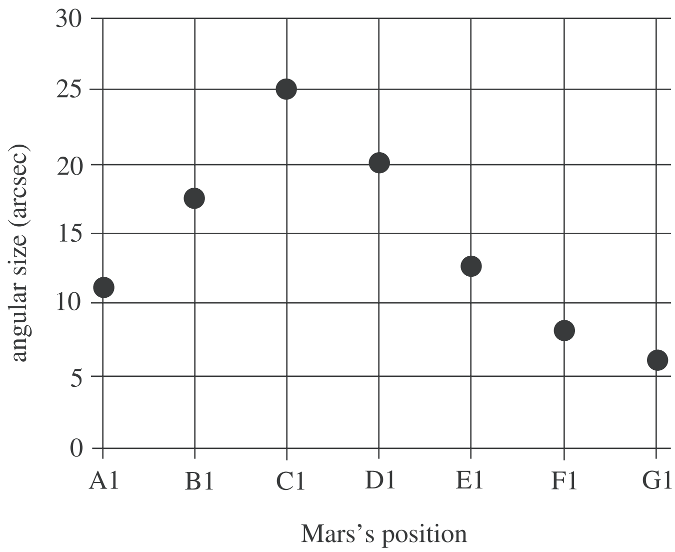
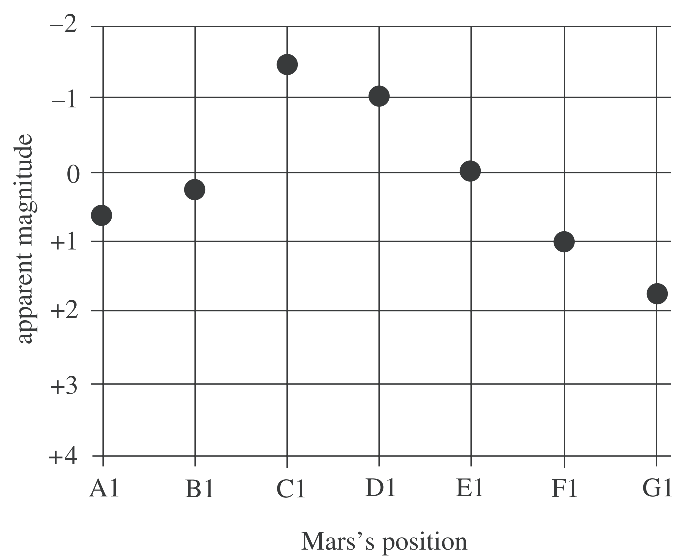


Figure 2



(Note: 1 arcsecond = 1/3,600th of a degree.)

Figure 3



(Note: Brightness increases as magnitude becomes more *negative*.)

Figure 4

Earth/Space Science Research Summaries passage for sample test question found on page 17

A soil's *texture* is the proportion of its particles that fall within 3 size categories: sand (the largest), silt, and clay (the smallest). Texture affects the rate at which water can drain through a soil. Soils high in sand commonly drain quickly, since there is a relatively large amount of interconnected space between sand grains. Soils containing large proportions of silt or clay particles drain more slowly, since the spaces between their particles are relatively small and not well connected.

The following experiments were conducted to investigate the effect of texture on the drainage of water through different soils.

Study 1

Samples of 5 soils were collected. All particles larger than sand were removed from each sample by passing the sample through a screen. Next, each sample was passed through 2 screens: The first trapped the sand-size particles; the second caught the silt particles, but allowed the clay to pass through it. The percentage (by weight) of the different particle sizes is shown in the table.

Soil type	Percentage sand	Percentage silt	Percentage clay
Sandy loam	65	20	15
Loam	40	42	18
Clay loam	34	31	35
Silty loam	17	70	13
Silty clay	10	45	45

Study 2

Three funnels were lined with filter paper, and into each one was placed an equal-size sample of a different soil: sandy loam, clay loam, and silty clay. A volume of 250 mL of water was poured into each funnel. The amount of water that passed through each sample, and the time it took for the water to stop draining through each sample, are as follows: sandy loam—150 mL, 75 sec; clay loam—125 mL, 90 sec; and silty clay—63 mL, 150 sec.

Biology Research Summaries passage for sample test questions found on pages 17 and 19

Germination, the initial growth of a seed, affects the yields farmers can obtain from their crops. Several factors are known to affect germination. The following experiments were conducted to determine the factors that influence the rate and amount of germination in corn.

Experiment 1

Four samples of 100 corn seeds each were placed on moist filter paper in separate petri dishes. The petri dishes were covered and the edges taped to prevent evaporation. Each sample was incubated at a different temperature. The germinated seeds were counted at 7, 14, and 21 days. The results are given in Table 1.

Table 1

Sample	Temperature (°C)	Total seeds germinated		
		7 days	14 days	21 days
1	5	0	0	0
2	20	25	37	44
3	35	50	70	80
4	50	2	3	3

Experiment 2

One sample of 100 corn seeds was placed in a moist petri dish, as described in Experiment 1. Another sample of 100 corn seeds was treated with a plant hormone prior to being placed in a moist petri dish. Both samples were incubated at 35°C. The germinated seeds were counted over 7-day intervals as in Experiment 1. The results are given in Table 2.

Table 2

	Total seeds germinated		
	7 days	14 days	21 days
Untreated	48	65	79
Treated	65	75	82

Experiment 3

Samples of hormone-treated (HT) and untreated (U) corn seeds were prepared as in Experiment 2. Four samples of 100 seeds each were treated with hormones and incubated at 5°C, 20°C, 35°C, and 50°C, respectively. Four more 100-seed samples were left untreated and incubated at the same temperatures as the treated samples. The germinated seeds were counted over 7-day intervals. The results are given in Table 3.

Table 3

	Total seeds germinated					
	7 days		14 days		21 days	
Temperature (°C)	U	HT	U	HT	U	HT
5	0	0	0	0	0	0
20	28	35	39	43	44	45
35	52	67	65	76	80	82
50	2	3	3	3	3	3

Biology Research Summaries passage for sample test questions found on pages 17 and 20

Penicillin kills certain bacteria, such as *Staphylococcus aureus (S. aureus)*. Other bacteria, such as *Streptomyces albus (S. albus)*, are *resistant* to penicillin because they produce and secrete *penicillinase*, an enzyme that destroys penicillin. Two experiments were done to study the effects of penicillinase.

Experiment 1

Researchers added *S. albus* to 500 mL of nutrient broth and incubated the mixture at 37°C for 5 days. Each day, the researchers removed and sterilized 10 mL of the mixture by filtration and then placed it in a test tube.

The researchers added 1 mL of penicillin to each tube; to a sixth tube only sterilized nutrient broth was added. All tubes were adjusted to a pH of 7.4 and incubated at 37°C for 2 hours.

Next, the researchers added *S. aureus* to each tube, incubated the tubes at 37°C for 48 hours, and checked for growth of *S. aureus*. The results are shown in Table 1.

Table 1

Tube	Incubation time for *S. albus* (days)	Penicillin added (mL)	Growth of *S. aureus*
1	1	1	no
2	2	1	no
3	3	1	no
4	4	1	yes
5	5	1	yes
6	0	0	yes

Experiment 2

Researchers added *S. albus* to 500 mL of nutrient broth and incubated the mixture at 37°C. On the fifth day, researchers removed and sterilized 10 mL samples of the mixture by filtration, placed each into a test tube, and adjusted the pH.

The researchers then added 1 mL of penicillin to 4 of the tubes and incubated all tubes at 37°C for 2 hours.

Next, the researchers added *S. aureus* to every tube, incubated the tubes at 37°C for 48 hours, and checked for growth of *S. aureus*. The results are shown in Table 2.

Table 2

Tube	pH	Penicillin added (mL)	Growth of *S. aureus*
7	5.0	0	no
8	5.0	1	no
9	6.1	0	yes
10	6.1	1	no
11	7.4	0	yes
12	7.4	1	yes
13	8.5	0	yes
14	8.5	1	no

Chemistry Research Summaries passage for sample test questions found on pages 17 and 19

Enzymes are compounds that act as catalysts for chemical reactions that occur in living systems. *Catalysts* increase the rates of chemical reactions, but are not used up in reactions. The *activity* (effectiveness) of an enzyme is affected by temperature. If the temperature is either too low or too high, the enzyme will not function at all.

Experiment 1

Beakers containing 4 equivalent starch solutions were placed in baths with temperatures of either 0°C, 25°C, 37°C, or 100°C. After 3 minutes (min), a sample was removed from each beaker and checked for the presence of starch by adding iodine (which changes from brown to dark blue if starch is present). The samples were checked again after 10 min and 30 min and the results were recorded in Table 1.

Table 1

Time (min)	Temperature (°C)			
	0	25	37	100
3	+	+	+	+
10	+	+	+	+
30	+	+	+	+

Note: “+” indicates starch is present,
“–” indicates starch is absent.

Experiment 2

Amylase, an enzyme found in human saliva, speeds the breakdown of starch into simple sugars, such as *maltose*. Experiment 1 was repeated, but equal amounts of amylase were initially added to each starch solution (see Table 2).

Table 2

Time (min)	Temperature (°C)			
	0	25	37	100
3	+	+	–	+
10	+	–	–	+
30	–	–	–	+

Note: “+” indicates starch is present,
“–” indicates starch is absent.

Experiment 3

Maltose can be detected by adding *Benedict’s solution* to a sample and boiling it. The light blue solution will produce an orange solid if maltose is present. Experiment 2 was repeated, but the solutions were tested with Benedict’s solution instead of iodine (see Table 3).

Table 3

Time (min)	Temperature (°C)			
	0	25	37	100
3	–	–	+	–
10	–	+	+	–
30	+	+	+	–

Note: “+” indicates maltose is present,
“–” indicates maltose is absent.

Chemistry Research Summaries passage for sample test question found on page 18

Students performed the following experiments to investigate the amount of H_2O in various substances.

Experiment 1

A sample of margarine of known mass was placed in a beaker. The sample was heated until it was completely melted. Upon cooling, a solid layer formed on top of a liquid layer. A hole was made in the solid and the liquid was poured out. The remaining solid was weighed and the percentage of H_2O in the margarine was calculated. Table 1 shows the results for 4 types of margarine.

Table 1

Margarine	Mass of margarine (g)	Mass of remaining solid (g)	% H_2O
A	16.83	16.29	3.20
B	24.07	12.51	48.03
C	19.59	15.16	22.61
D	23.41	10.30	56.00

Experiment 2

A sample of lotion was placed in a preweighed beaker and weighed. The sample was heated in an oil bath for 30 minutes. Upon cooling, the outside of the beaker was wiped clean and the beaker and its remaining contents were weighed. The percentage of H_2O in the lotion was calculated. Table 2 shows the results for 4 types of lotion.

Table 2

Lotion	Initial mass of lotion sample (g)	Final mass of lotion sample (g)	% H_2O
E	40.94	31.32	23.50
F	33.46	27.46	17.93
G	34.86	27.91	19.94
H	24.15	19.55	19.05

Experiment 3

Hydrates are chemical compounds that contain H_2O. *Anhydrous* compounds contain no H_2O. A sample of a chemical compound was placed in a dry, preweighed ceramic crucible and weighed. The sample was heated with a flame for 10 minutes, then cooled in a dry atmosphere and weighed. This procedure was repeated until the mass did not change. The percentage of H_2O in the compound was calculated. Table 3 shows the results for 4 different compounds.

Table 3

Compound	Initial mass of sample (g)	Final mass of sample (g)	% H_2O
J	1.03	0.67	35
K	1.31	0.72	45
L	1.22	0.93	24
M	1.27	1.27	0

Appendix
Passages Corresponding to Sample Test Questions

Biology Conflicting Viewpoints passage for sample test questions found on page 19

When gazelles see a predator, they run away to escape *predation* (being eaten). Sometimes, however, while running away, a gazelle will *stot* (briefly slow down and jump in the air with its legs extended back and its white rump patch exposed). A number of hypotheses have been suggested to explain why gazelles stot. Four of these hypotheses are given below.

Alarm Signal Hypothesis

Only grouped gazelles stot. When a group of gazelles are together and one gazelle sees a predator, it will stot to warn the other gazelles. It stots by pointing its white rump patch toward the other gazelles, increasing the other gazelles' ability to escape predation.

Social Cohesion Hypothesis

Only solitary gazelles stot. If a gazelle is separated from the other gazelles and it sees a predator, the gazelle stots to signal the other gazelles to form a herd. It stots by pointing its white rump patch toward the other gazelles. This is done because herding makes it difficult for a predator to separate one gazelle from the rest of the herd. Since a predator needs to separate a victim from the herd, grouped gazelles are less likely to be captured by a predator.

Confusion Effect Hypothesis

Only grouped gazelles stot. They stot to confuse predators. When many gazelles stot simultaneously, pointing their white rump patches at a predator, the predator has difficulty focusing on a single gazelle. Therefore, all of the gazelles have a better chance of escaping predation.

Advertisement of Unprofitability Hypothesis

Only solitary gazelles stot. If a gazelle is isolated and a predator has chosen it for predation, the gazelle will stot to tell the predator that it is aware of the predator's presence. The gazelle stots by pointing its white rump patch at the predator. This signal may convince the predator to abandon the chase, since the element of surprise is no longer on the predator's side.

Earth/Space Science Conflicting Viewpoints passage for sample test question found on page 20

Radon is a radioactive gas formed from the decay of radioactive materials (such as uranium or radium) in soil, bedrock, underground water, and air. In four days or less, half of any sample of radon decays into other products. Radon's radioactivity can be harmful to humans if radon is breathed at high levels over long periods of time. In recent years, this has been recognized as a problem in many homes throughout the world.

Radon concentrations are measured in picocuries per liter (pCi/L). The picocurie is a measure of radioactivity. Outdoor air is very low in radon, usually less than 1 pCi/L. Levels in a home that are greater than 4 pCi/L are considered potentially harmful.

Two scientists have different opinions about how radon enters a home.

Scientist 1

Radon enters a home in the water piped into a house or with groundwater that seeps into the basement through cracks in floors and walls. Drinking water, especially well water, picks up radon from the rocks and soil it passes through before entering the house. Turning on the faucet releases a burst of radon into the house. The more the water is aerated, such as during a shower, the more radon is released. This gas either decays or slowly escapes from the house through open doors, windows, or other exits, but more gas enters each time the water is turned on.

Scientist 2

Only a very small amount of radon enters with drinking water and groundwater. Rocks and rock particles in the soil continuously release radon. Most radon enters a home with *soil gas* (a mixture of air and other gases found in soil), which seeps into a house through those parts of the house in contact with soil or bedrock. This occurs whether or not water is present. Some rocks contain materials that produce radon, so concrete used in building a house may be a potential source of radon. Radon collects in the lowest levels of a house. During times when the house is closed up, the radon levels can rise higher than at times when the house is opened up.