Challenge to Lead

SREB

HIGH SCHOOLS THAT WORK

Making Middle Grades Work

Making Schools Work

Getting Students Ready for College-preparatory/ Honors Science:

What Middle Grades Students Need to Know and Be Able to Do

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Foreword

The Southern Regional Education Board (SREB) has adopted 12 *Challenge to Lead* Goals for Education which assert that SREB states can lead the nation in educational progress. One of these goals includes getting middle grades students ready to do challenging high school studies:

Achievement in the middle grades for all groups of students exceeds national averages and performance gaps are closed.

According to *The Nation's Report Card* in 2000, 39 percent of eighth-graders performed below the Basic level in science as measured by the National Assessment of Educational Progress (NAEP), while the 2002 SREB middle grades data indicate that 44 percent of students at 95 middle grades schools performed below the Basic level. One of the reasons for this poor performance is the lack of a challenging and meaningful science curriculum taught by teachers with a deep knowledge of science who can teach in ways that motivate students to make the effort to meet higher standards. Based on a 2002 survey of 7,266 eighth-graders at 95 *Making Middle Grades Work (MMGW)* schools, 23 percent reported that they were never required to complete a written lab report, 33 percent never chose a problem for investigation and 30 percent never designed an experiment. Poor performance and preparation in the middle grades translate into high schools retaining their old placement practices of enrolling nearly two-thirds of freshmen in lower level science courses.

Identifying essential readiness indicators for ninth grade college-preparatory science is one way to establish content standards for middle grades science classrooms. While many states have set content and performance standards in science, often these standards have not been translated at the school level into student assignments, investigations and classroom assessments that reflect what students should know and be able to do. Surveys of teachers in over 200 middle grades schools indicate that the most important goal is to get students through grade eight.

The Southern Regional Education Board's *MMGW* **staff worked with a panel of teachers and experts from the Educational Testing Service (ETS) to develop a set of readiness indicators for high school science.**

The panel reviewed the National Assessment of Educational Progress, the Third International Mathematics and Science Study (TIMSS), the National Science Teachers Association (NSTA) and SREB data and materials on science standards, curricula and course-taking patterns. From these reviews, a list of essential process and content indicators was developed. The five process indicators and 14 content indicators provide a foundation on which schools can build comprehensive science programs.

Based on their judgments, the panel members — using NAEP as a reference — developed definitions of the Basic, Proficient and Advanced levels of science proficiency. The panel used its definitions to determine the proficiency level for each item on the Benchmark Proficiency Progression charts, the Learning Activities and the illustrations of assessment items in this report. The process the panel used was less complex than the process used by NAEP. Therefore, **the panel's determinations of the proficiency levels are not to be construed as equivalent to the NAEP process.**

This report is not intended to answer all curriculum-related questions, to serve as a complete teaching plan or to replace state-mandated science curriculum standards. **It is a tool to help middle grades administrators and teachers set goals and priorities for science instruction that will get all students ready for college-preparatory science in high school.** This report is designed to assist curriculum planners, principals and teachers in developing curriculum frameworks, course syllabi, lesson plans, assignments and assessments for middle grades science classrooms. Further, it can be used to plan staff development activities that will enable teachers to better prepare students to meet the demands of laboratory-based college-preparatory science courses.

This report provides guidance for a rigorous science curriculum in the middle grades based on a solid set of essential standards that can prepare all students to perform at least at the Basic level of proficiency and for increasing percentages of students to perform at the Proficient and Advanced levels.

Gene Bottoms
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Why Develop Readiness Indicators for Rigorous High School Science?

"The American public's level of scientific literacy and general technical preparedness are not adequate to meet the needs of the changing economy."[1] In fact the majority of Americans do not believe that students are being adequately prepared in technical literacy and science.[2] Advances in science and technology continue to provide us with the ability to change our world and the way we live, but these advances require specialized skills. Dealing responsibly with contemporary societal issues — the highly technological workplace, global warming and air pollution — and with personal issues — energy conservation, food and nutrition, and medical treatments and medications — requires a firm grasp of scientific concepts and the ability to apply scientific thinking to a variety of situations.

With state accountability programs now operating or scheduled in every SREB state, schools, districts and states have compelling needs to raise students' science achievement — especially in the middle grades. The federal No Child Left Behind Act of 2001 gives schools a further incentive to improve science achievement to have all groups of students perform at least at the states' defined levels of Proficient in science.

Science achievement begins to drop off in the middle grades and then drops more rapidly in high school. In 2002, the NAEP science assessment results indicate that 34 percent of fourth-graders, 39 percent of eighth-graders and 47 percent of 12th-graders scored below the Basic level.

In 2000, SREB conducted a follow-up study of nearly 3,100 students from 44 middle grades and 38 high schools. Results indicated that only nine percent of students overall enrolled in college-preparatory science in grade nine and only 11 percent planning to go to college enrolled in college-preparatory science. In 2001, a second SREB study of 4,244 seniors at 51 rural high schools showed that only 36 percent took college-preparatory biology, 21 percent took college-preparatory physical science and 21 percent took physics. As the data show, too many high schools continue to follow old placement practices and too few students enroll in challenging science courses that will prepare them to apply scientific thinking in our highly technological society.

Placing ninth-graders in lower-level science courses is not the answer to failure rates. According to the 2001 ninth grade follow-up study, almost two out of five eighth-graders scoring in the lowest two quartiles in science achievement *fail* whatever science course they take in grade nine. However, when these students are enrolled in higher-level courses, they are *not* more likely to fail. Of all eighth-graders scoring in the lowest quartile on the 2001 NAEP-referenced science assessment, the failure rate was 48 percent if they were placed in college-preparatory ninth grade science and 44 percent if they were placed in low-level science. For students scoring in the second lowest quartile, the failure rate in college-preparatory science was 23 percent compared to 33 percent who failed low-level science. Given quality teaching, extra time and help, even more of these low-performing students could succeed at higher levels.

Obtaining and succeeding in the good jobs in today's economy require an ever-increasing breadth and depth of scientific and technical knowledge and skills. According to *The Skills Gap 2001* published by the National Association of Manufacturers, 26 percent of companies cited inadequate technical/computer skills, 23 percent inadequate problem-solving skills and 24 percent an inability to work in a team environment as some of the most common reasons candidates are rejected.[3] The following table from that study shows how the companies viewed shortages in particular job areas that require some level of scientific knowledge.

Shortages of Qualified Candidates

Job Area	Moderate to Serious Shortage
Operators	76%
Machinists	75
Technicians/electricians	75
Craft workers	77
Engineers	65
Scientists/R and D workers	48

[1] National Science Board
[2] Bayer Facts of Science Education IX: American's Views on the Role of Science and Technology in U.S. National Defense, Bayer Corporation, 2002.
[3] Center for Workforce Success and Andersen, *The Skills Gap 2001*, National Association of Manufacturers, 2001.

According to *Reality Check 2002*[4], 42 percent of employers cite lack of mathematics knowledge and skills, 26 percent problem solving and 15 percent vocational skills as the greatest deficiencies K-12 schools have in preparing students for the workplace. Success in college-preparatory science courses can lead to more — and better — opportunities after high school. This success will not occur without a correspondingly rigorous science curriculum in the middle grades.

Many middle grades teachers are teaching science courses that are not aligned to a set of indicators aimed at getting students ready for *rigorous* high school science. As a consequence, too few middle grades teachers require students to master essential scientific concepts or provide them with opportunities to do the necessary amount of investigative research. There are numerous curriculum documents at the national, state and district levels that provide standards and frameworks regarding what students should learn in middle grades science. However, teachers need additional guidance about the depth and breadth of knowledge and skills students need on the most essential readiness indicators for challenging, laboratory-based high school science. Holding each student accountable when working in teams for brainstorming, researching answers to essential questions and defending answers are activities that prepare students for the level of analysis and quality of work they will encounter in challenging high school science courses.

How Were the Readiness Indicators Developed?

Building a rigorous middle grades science curriculum begins with two questions:

- **What are the essential scientific knowledge and skills — Readiness Indicators — students must master by the end of the middle grades in order to succeed in college-preparatory science courses in high school?**
- **What are some examples of the proficiency levels for each of the Readiness Indicators?**

Preparation of this report began with these two questions and a review of major national, state and district science curriculum documents including:

- the National Science Teachers Association's *Pathways to the Science Standards*,
- the American Association for the Advancement of Science's *Benchmarks for Science Literacy*,
- the National Research Council's *National Science Education Standards*,
- curriculum frameworks underlying the National Assessment of Educational Progress (NAEP), and
- curriculum guides from the SREB Middle Grades Consortium member states and selected other states.

An analysis of these frameworks yielded a lengthy list of standards for middle grades science. The panel members selected from this list those curriculum standards that represent the most essential knowledge and skills for success in college-preparatory science. Identifying standards that are most important for high school success ensures that essential material does not fall through the cracks — either for lack of time or because it is too challenging. Panel members used several questions to narrow their selections of essential indicators:

- What knowledge, skills and experiences in science do students entering high school most often lack that they should have acquired in earlier grades?
- What skills, knowledge and experiences in science separate students who enter and succeed in a rigorous high school science curriculum from those who do not?
- What skills and knowledge in science that students should acquire in the middle grades take the most time to reteach?
- What deficiencies in knowledge and understanding are most difficult to remedy and which ones continue to plague students in later courses?

[4] *Reality Check 2002*, Public Agenda at www.publicagenda.org.

After numerous telephone conferences and e-mail communications, the panel reached a consensus on the essential knowledge and skills required for success in science — the 19 Readiness Indicators in this report. Then with the help of ETS and the *MMGW* staff, the panel developed the definitions of Basic, Proficient and Advanced levels of science performance at grade eight. (See page 9.) These definitions guided the development of the Benchmark Proficiency Progression charts and the Learning Activities for each indicator in the report.

Panelists reviewed various assessment items including the publicly-released NAEP items and made judgments about which items best illustrated their definitions of the proficiency levels. These judgments are not to be construed as equivalent to the NAEP standards of Basic, Proficient and Advanced. Then panel members and other science experts reviewed numerous drafts of the report and made suggestions for strengthening it.

How Is the Report Organized?

This report is organized around 19 Readiness Indicators: five Process Readiness Indicators and 14 Content Readiness Indicators. These 19 indicators represent the essential knowledge and skills for investigative-based college-preparatory high school science. Content knowledge and process skills are at the core of a solid science curriculum and each is an integral part of the other. The description of each Readiness Indicator includes examples of how the indicator relates to the preparation of students for rigorous high school science and suggestions to help teachers teach the concepts and skills.

Each of the Content Readiness Indicators, grouped by subject area — earth/space science, physical science and life science — provides an idea to "launch" students into thinking critically by using prior knowledge, brainstorming and researching information to set the stage for possible investigations. Following the launch idea is a *Benchmark Proficiency Progression* chart listing major benchmarks at each proficiency level. These charts help teachers and administrators identify the knowledge and skills that students must master to succeed in college-preparatory science.

While many students are performing below the Basic level in science achievement, **the *Making Middle Grades Work* goal is to get *all* groups (socio-economic, ethnic/racial, male/female) of students to achieve at least at the Basic level and increasing percentages at the Proficient and Advanced levels.** Students who achieve at least at the Basic level are considered minimally prepared for a rigorous high school program. In this report, descriptions are provided for the Proficient and Advanced levels to help curriculum planners compare how consistent their curricula are with the requirements of a rigorous high school program. The intention is to ensure that middle grades instruction does not end at the Basic level and to make it clear when students are truly performing at the Proficient and Advanced levels. The *MMGW* initiative is based on the belief that students with quality teaching and quality extra help and time will be successful in college-preparatory science.

Benchmark Proficiency Progression

Basic*	Proficient*	Advanced*
All students should reach at least this level by the end of grade eight. Students at this level can succeed in college-preparatory science if given highly qualified teachers, enough extra time and help.	Most students will reach the Proficient level by the end of the middle grades. All students will master rigorous content material at or above this level. Students with high quality teachers that thoroughly engage them should succeed in college-preparatory science, given opportunities for extra time and help.	Some students will reach the Advanced level by the end of the middle grades. Others will reach this level by the end of the ninth grade. Students at this level usually excel in college-preparatory science.

* These three proficiency levels are based on the categories used by the NAEP-based assessment of student progress. (See page 7.)

To illustrate how essential it is that the Process Readiness Indicators are correlated with a Content Readiness Indicator, a complete sample investigation follows Indicators 5, 10 and 14.

The five Process Indicators encourage hands-on, inquiry-based science. Students learn by doing. When teachers present interesting questions or problems and guide the research, investigation and presentation of information answering the questions, students achieve at higher levels. However, the sequence of teaching most often observed in science classrooms is lecturing followed by answering questions, completing worksheets and ending with a test. **What is envisioned is a different sequence that begins with an essential question or scenario and a laboratory experience, followed by discussion, an oral or written report, a lecture and a test — thus sequencing the lesson from hands-on to abstract.**

Next are activities that represent suggestions for Basic, Proficient and Advanced assignments. All of these activities encompass one or more of the five Process Readiness Indicators — taught not in isolation, but integrated into the teaching of the Content Indicators. The *Learning Activities and Applications* emphasize building a foundation of conceptual understanding. Extending science instruction beyond memorizing facts is necessary, not only to generate student interest, increase motivation and challenge students intellectually, but also to help them realize the importance of science in their everyday lives and in their futures.

The section containing the 14 Content-specific Readiness Indicators provides test-item examples called *Proficiency Level Illustrations*. The sample test items assess the depth of understanding students must master to achieve at each proficiency level. Many of the examples are publicly released items from NAEP and from TIMSS while others have been created specifically for this report.[5]

How Can Educators Use this Report?

The 19 Readiness Indicators can guide curriculum planners, principals and teachers in examining what they currently teach, how they teach it, and how deeply they engage students in each of these areas of scientific knowledge and skills necessary for success in rigorous high school science. Teachers can use the Readiness Indicators to identify weaknesses in their assignments, assessments, process skills and gaps in their local curriculum guides. To help them make these identifications, they should ask these types of questions:

- Are these essential topics given the time and depth of coverage necessary to prepare students for college-preparatory science?
- Are there other topics that are given too much attention so that topics crucial for success in college-preparatory science are not fully developed or not included at all?

Teachers can examine current standardized test results to see which items their students are answering incorrectly. An analysis of the test results and a comparison to the Readiness Indicators provide information to help educators target content and skill areas to improve student achievement. This report can help school leaders and teachers achieve a clear and consistent understanding of what does and does not meet standards.

Curriculum planners, principals and teachers can use the sample *Learning Activities and Applications* at each proficiency level to help them evaluate student assignments. By examining a collection of assignments based on one or more of the readiness indicators, they can determine the levels of the assignments. School leaders and teachers need to frequently ask these types of questions:

- What is the most frequent level of assignment given? What percentage of assignments is at the Basic level or below? Proficient level? Advanced level?
- As a result of looking at the level of assignments, are teachers increasing the percentage of higher level assignments?
- Are teachers decreasing the number of short-answer and multiple-choice questions, and increasing the number of essay and open-ended response questions?
- Are students given more opportunities to design and conduct increasingly complex research and investigations?

[5] All items were labeled at given proficiency levels by the panel members and not by the organizations associated with those assessments.

The sample test items at each proficiency level guide teachers in developing test items to determine how their students perform on the various indicators. School leaders and teachers can gather a sample of their own science classroom exams to determine what proportion of their test items are below the Basic level or at the Basic, Proficient or Advanced levels. **If students are never given Proficient- or Advanced-level assignments and are not assessed at these levels, then students cannot be expected to achieve at these levels.**

Most of the Proficiency Level Illustrations are from two outside sources, but some were written by the panel for this report. In most cases, the items from the outside sources appear as originally published, but in some cases, multiple-choice items have been converted to open-ended items. These cases are noted. The two outside sources are

- the National Assessment of Education Progress (NAEP), Eighth Grade Science Assessment, 1996 and 2000, National Center for Education Statistics, U.S. Department of Education; and
- the Third International Mathematics and Science Study (TIMSS), 1995 and 1999 Reports, International Association for the Evaluation of Educational Achievement (IEA).

Finally, educators need to examine *how* each of these indicators is taught. Quality engagement is not just busy work, but minds-on, hands-on student-centered work that constantly raises the level of expectations for each student.

Questions to be answered include

- Are students given real-world scenarios to investigate that help them understand how science is used to solve problems in real-life situations?
- Are the scenarios complex enough to force students to use logical reasoning and analytical strategies as well as their science knowledge and skills?
- Are students sharing their design ideas for investigations with a team? Are they communicating and defending their findings to the class?
- Are students required to use science equipment in activities and research projects?
- Are students using technology to aid them in the analytical process?
- Are students reading, writing, speaking and presenting using scientific language?

Students need to be challenged by interesting materials and provided the extra time and help they need to improve their achievement. Rather than experiencing low expectations, students are engaged in rigorous and meaningful work that motivates them to meet and exceed expectations.

Each process and content indicator provides the essential skills and knowledge that students must have if they are to be successful in college-preparatory courses in high school and if science achievement is to increase. The indicators in this document form the critical core of what must be taught in middle grades science classes, regardless of whether science is taught in discrete courses or as integrated science.

SREB Performance Descriptors for Grade Eight Science

Basic

Students performing at the Basic level are able to recall fundamental scientific facts and recognize basic concepts when presented in a multiple-choice format. However, these students do not link concepts together, such as in cause-effect relationships. They can plot data from tables; read scales on basic laboratory equipment; and read and interpret tables or graphs and draw appropriate conclusions or apply them to practical situations. They can apply scientific reasoning to solve two-step problems. Students at this level have some basic laboratory skills and are familiar with scientific investigations and the scientific method. They know correct terminology for scientific investigations and can recognize appropriate experimental designs.

At the Basic level, students are familiar with elementary concepts in different fields of science. For example, in **life science**, they know the difference between inherited and acquired traits; recognize characteristics that classify living things; recognize hierarchy within a food chain; and recognize characteristics and requirements of living things. They have a fundamental knowledge of photosynthesis and of human systems.

In **physical science**, students know physical properties of matter such as solubility and states of matter, can complete simple electrical circuit diagrams, recognize how sound travels, and identify how forces act on a body.

In **earth science**, students have basic knowledge about the properties of Earth's surface and the characteristics of minerals. They are aware that Earth's top layer is made up of continental plates that move; know that the fossil record is evidence of the history of life on Earth; and know how the fossil record can be interpreted. Students at this level demonstrate some basic knowledge of Earth's relationship to other objects in space and have some understanding of the interaction of humans with Earth such as the human impact on the environment and its resources. Skills related to earth science at this level include using a scale in reading a geographic map.

Proficient

In addition to Basic level knowledge and skills, students performing at the Proficient level have a clearer understanding of natural processes and can recognize some cause and effect relationships. Students' knowledge of the scientific method and scientific investigations is more fully developed. For example, students can design simple experimental procedures such as separating mixtures based on physical characteristics.

At the Proficient level, students can demonstrate understanding of processes such as modes of energy transfer through conversion of light energy to heat energy. Students recognize cause and effect relationships such as how predator-prey relationships affect populations; the causes of extinction; the human impact on the environment through specific knowledge on causes of pollution such as acid rain; and forces that cause continual changes to the surface of Earth.

Advanced

In addition to knowledge and skills present at the Basic and Proficient levels, students performing at the Advanced level are able to conceptualize more advanced processes, and have well-developed skills related to scientific investigations. Students can determine essential questions and design experimental procedures that include controls and variables when appropriate for the investigations. Using complex data tables, students can derive general relationships between variables. They can synthesize data from multiple sources (e. g., recognizing patterns) and make appropriate predictions. Students can design multi-step experimental procedures such as separating mixtures based on physical characteristics. They are aware of sources of experimental error and can give suggestions for the experimental design to reduce error in the results.

In content areas, students at the Advanced level can sequence levels of organization in living systems; recognize that the force of gravity depends on mass and distance; and recognize effects of differences in heating and cooling rates between Earth's land and water surfaces.

Process Readiness Indicators:
The steps in scientific investigations*

Science and mathematics, in particular, hold similar goals for students — to develop their problem-solving and process skills. The Process Indicators for science are patterned after the steps in the scientific method and provide students with experiences that support meaningful scientific investigations that engage them in learning the science curriculum.

All students are capable of *conducting scientific investigations* — in fact, most middle grades students are naturally inquisitive. The middle grades science teacher can transform students' natural inquisitiveness into more disciplined and formalized ways of asking questions and presenting information. Developing scientific thinking is an integral part of everyday science instruction and not something reserved for occasional activities. If students are to be successful in college-preparatory science courses in high school, they must have these experiences. Good teachers guide individual students and groups of students in conducting scientific investigations at all levels of sophistication. In group assignments each student is held accountable for all of the essential learning associated with the investigation or project. Even with basic investigations and simple designs, students gain valuable experience in framing appropriate questions to *communicate and defend their findings, analyzing their findings and applying their results to other questions and investigations.*

Acceptable scientific practices shape the *design of a scientific investigation*, the observations, and the recording and analysis of data. Students in the middle grades can gain skills and knowledge in posing questions as teachers guide the questioning process to ensure that students pose relevant questions, seek answers and develop solutions — key elements in scientific investigation.

Process Readiness Indicators:

1. **Design a Scientific Investigation**
2. **Conduct a Scientific Investigation**
3. **Analyze the Findings of a Scientific Investigation**
4. **Communicate and Defend Findings**
5. **Evaluate Other Scientific Investigations and Apply Results**

Conducting a variety of scientific investigations prepares middle grades students for the extensive laboratory work they will face in high quality college-preparatory science courses at the high school level. The hands-on explorations of important science content provide a rich background of understanding that students will need in those courses. Understanding the process of scientific investigation gives students a greater understanding of how scientific knowledge is developed, refined and expanded. It also gives students the basis by which they can distinguish among scientific laws, theories, hypotheses and conclusions.

The Process Indicators include skills essential for investigating and understanding science. The following charts give examples of progressions at each proficiency level. They are described in more detail later. A sample rubric for evaluating student scientific investigations is on page 13.

*** Teachers must carefully follow state and/or district safety guidelines for all scientific investigations and activities.**

Benchmark Proficiency Progression

	Basic	Proficient	Advanced
1. Design a scientific investigation.	Identify the essential research question and select the investigative design that best answers the question.	Identify the essential research question; use information from previous investigations and design an investigation to answer the question; predict the outcome.	Identify related research questions; form a hypothesis and design a multi-step investigation to answer one of the essential research questions.
2. Conduct a scientific investigation.	Complete the steps listed in the investigative design (as directed by the teacher) and carefully record the data.	Complete the steps (with teacher assistance) in the investigative design that addresses the essential question and record the data at regular intervals.	Complete a complex multi-step investigation according to students' planned designs; monitor the variables and record the data.
3. Analyze the findings of a scientific investigation.	Review the data and form conclusions; answer questions about the results.	Review and analyze the data and provide details to support predictions and conclusions.	Analyze the data and determine factors that affect the outcome; improve the design of the investigation.
4. Communicate and defend findings.	Present a written or oral report that provides evidence of understanding the variables; include a simple graphic.	Write a comprehensive summary of the steps, design and conclusions; use graphics to present and defend findings.	Write a research report detailing the complete investigation; develop a multimedia presentation to present and defend findings.
5. Evaluate other scientific investigations and apply results.	Review other investigative designs and conclusions; answer questions about the differences in the investigations.	Evaluate other investigative designs; improve the design to overcome any problems in one of the designs. Present changes and details about the changes.	Evaluate other investigative designs; improve the design to test the new hypothesis. Conduct the investigation and present conclusions resulting from the improved design.

1 Design a Scientific Investigation.

To be successful in college-preparatory science classes, the most important skill for students to have when they leave the middle grades is the ability to design a scientific investigation to answer questions or solve a problem. Some of these investigations can be elaborate while others can be simple and short, but all are aligned to the middle grades curriculum. An investigative approach gives students the opportunity to experience the strategies used by real-life scientists and scientific teams. Students' experiences in scientific investigations provide the tools for them to design experiments that include observing, thinking, experimenting and validating results. All students can ask and answer the following types of questions:

- What is the essential research question?
- How will the answer to the question be determined?
- How can the phenomenon be isolated or simulated so it can be observed and measured?
- What external variables might influence the results?
- How can the external variables be controlled?
- Is the design of the experiment feasible and will it produce valid results?

Benchmark Proficiency Progression

Basic	Proficient	Advanced
Identify the essential research question and select the investigative design that best answers the question.	Use information from previous research and design an investigation to answer the essential question; predict the outcome.	Critique related research questions; design a multi-step investigation to answer one of the questions.

2 Conduct a Scientific Investigation.

Middle grades students are expected to recognize that the success of an investigation depends on more than just the results — it depends on how well students conduct and document the investigation to support or refute its hypothesis. They can carefully document the individual steps and results, adhere to safety guidelines and evaluate how deviations from the experimental design and procedures affect results. Students need to identify variables, and recognize the need for and difficulty in controlling them. These are critical skills needed in college-preparatory courses in high school.

Students must understand that eliminating or skipping steps or altering measurements can compromise the value of their work. Having students keep detailed records of their observations is invaluable in helping them organize and interpret their results. Computers, graphing calculators, graph paper and other materials can help students record and organize their data.

Benchmark Proficiency Progression

Basic	Proficient	Advanced
Complete the steps listed in the investigative design (as directed by the teacher) and carefully record the data.	Complete the steps (with teacher assistance) in the investigative design that addresses the essential question and record the data at regular intervals.	Complete a complex multi-step investigation according to students' planned designs; monitor the variables and record the data.

3 Analyze the Findings of a Scientific Investigation.

It is important that middle grades students develop judgment about whether the differences in the results of similar investigations are significant. They need to recognize that different results for similar investigations often call for additional investigations. Students must learn that scientists repeat investigations many times before accepting the results as correct.

Skills in analyzing are important in all college-preparatory science courses and must be taught to all students. To develop analytical thinking skills, students need to experience investigations involving phenomena and relationships unfamiliar to them — ones that require thorough and original analyses. Presently, in many middle grades scientific investigations, students do very little analytical thinking because an underlying concept is already known. Often students relate their observations by simply restating a fact or principle.

Students should learn to compare the original questions or problems to results and to recognize that their analyses of investigations must be supported by valid findings, and by clear and accurate records of their investigations. Students can learn to use computers and other available technology for collecting, retrieving, organizing and displaying data.

Benchmark Proficiency Progression

Basic	Proficient	Advanced
Review and plot the data, form conclusions, and answer questions about the results.	Review and analyze the data and provide details to support predictions and conclusions.	Analyze the data and determine factors that affected the results; derive relationships between variables and note sources of error.

4 Communicate and Defend Findings.

In high school college-preparatory classes, students are expected to describe and present — in oral and written form — the observations, step-by-step procedures and conclusions of their investigations. Middle grades students need practice in 1) communicating logically and systematically their investigative designs, procedures and results; 2) critiquing, analyzing or re-creating their work; and 3) using charts and illustrations to show the results of their work and support their findings. Students must anticipate questions to defend their work and develop responses in advance. These skills are learned in the middle grades.

Formal presentations of findings allow students to address classmates directly. These experiences provide excellent opportunities for students to act as scientists in a laboratory setting and use the language of science by sharing and critiquing each others' work.

Benchmark Proficiency Progression

Basic	Proficient	Advanced
Present a written or oral report that provides evidence of understanding of the variables; include a simple graphic.	Write a comprehensive summary of the steps, design and conclusions; use graphics to present and defend findings.	Write a research report detailing supportive data and describing the complete investigation; develop a multimedia presentation to present and defend findings.

5 Evaluate Other Scientific Investigations and Apply Results.

In college-preparatory science courses, students will critique the designs of investigations and the manner in which they were conducted; identify the validity of conclusions; and create new research questions based on the results. Students can describe whether conclusions from the investigations are supported scientifically. These skills must be taught in the middle grades so that all students are prepared for rigorous high school study.

The process of observing, participating in or reading about any scientific investigation helps develop students' abilities to reason scientifically. Discussions regarding the validity of findings generate ideas for new experimental designs which give meaning to the investigative process.

Key questions to help evaluate other students' investigations include

- How do the findings confirm or conflict with the hypotheses and results obtained by other teams?
- If the investigation is repeated, how can the design be improved?
- How can the investigations and findings be applied to situations outside the science class?
- How do the design and results impact other investigations or situations?

Benchmark Proficiency Progression

Basic	Proficient	Advanced
Review other investigative designs and conclusions; answer questions about the differences in the investigations.	Critique other investigative designs; improve the design to overcome any problems in one of the designs. Present changes and details about the changes.	Evaluate other investigative designs; improve the design to test the new hypothesis. Conduct the investigation and present conclusions resulting from the improved design.

Following is a sample rubric for evaluating student scientific investigations.

Rubric for a Scientific Investigation

Steps in an Investigation	Basic	Proficient	Advanced
1. Design a scientific investigation.	Investigative design allows comparison of variables to standards and includes an essential research question. (teacher-directed)	Investigative design allows comparison of variables to standards, includes sufficient tests to obtain some data and predicts the outcome; essential question focuses the investigation and demonstrates prior knowledge. (teacher-assisted)	The hypothesis clearly defines the design. Investigative design allows comparison of variables and sufficient tests to obtain meaningful data through a complex multi-step investigation.
2. Conduct a scientific investigation.	Hypothesis predicts with some facts; procedure applies some basic principles of scientific experimentation consistently and uses terminology appropriately; research is minimal. All steps are completed.	Hypothesis predicts with correct facts; procedure applies necessary principles of scientific experimentation consistently and understands and uses terminology appropriately; research is adequate and addresses the essential question.	Hypothesis predicts with correct facts and creates a new hypothesis; multi-step procedures and repeated trials apply principles of scientific experimentation consistently and uses terminology appropriately; research is extensive and has several complex steps.
3. Analyze the findings of a scientific investigation.	Data are randomly organized and general; conclusion shows some understanding.	Data are organized and fairly specific; charts or tables may be used; conclusion shows clear understanding of concepts learned.	Data are recorded systematically in charts, graphs or tables; conclusion shows understanding of the concepts and creates a new hypothesis to apply to other investigations.
4. Communicate and defend findings.	Answers are incomplete and/or partially correct; summary report is complete, but lacks sufficient supporting details.	Answers to questions are correct and show clear understanding of the investigation; summary report contains numerous supporting details; graphic display includes most steps in a logical sequence.	Answers to questions are correct and expansive; summary report contains extensive supporting details; graphic display includes all major steps in a clear and informative manner.
5. Evaluate other scientific investigations and apply results.	Evaluation includes comparison of design and procedure to similar investigations; there is a plan for revising the investigation.	Evaluation includes detailed comparison of differences in design and procedure of similar investigations; there is a plan for improving the investigative design.	Evaluation includes a logical explanation and reasons for changes in design and procedure to similar student projects and to other research; the new investigative design improves the validity and reliability.

Content-specific Readiness Indicators:
What students need to know and be able to do

These 14 Content-specific Readiness Indicators define the essential content needed to prepare students for college-preparatory laboratory science. While the indicators are arranged by content areas, **the order of the indicators on the list is not a teaching sequence, nor is it a ranking of topics from most important to least important.** The *Learning Activities and Applications* offer investigations at the Basic, Proficient and Advanced levels. Basic Activities are teacher-led, Proficient Activities are a combination of student-initiated and teacher-directed, while Advanced Activities are student-designed and directed. It is not intended to suggest that teachers begin with the Basic level and move toward the Advanced level. In fact, the opposite is true. Higher-level achievement occurs when teachers structure lessons that begin with challenging activities and guide student learning through investigation and research.

Upon leaving the middle grades, students achieving at the Proficient and Advanced levels are better prepared for rigorous high school science courses, while students achieving at the Basic level are minimally prepared and will need extra help and extra time to achieve at the college-preparatory/honors level.

Sample Investigations that model how the five Process Indicators are integrated with the content knowledge follow each group of indicators: Earth/Space Science (Indicators 1-5), Physical Science (Indicators 6-10) and Life Science (Indicators 11-14).

Content-specific Readiness Indicators

Earth/Space Science

1. **Describe processes that alter Earth's surface.**
2. **Know that rocks and fossils provide important evidence of how the physical earth and biological systems have changed over long periods of time.**
3. **Describe the position and movement of the major bodies of the solar system and current scientific theories of their origin.**
4. **Describe causes of weather events and changes in climate.**
5. **Describe the water cycle.**

Physical Science

6. **Explain that all substances (matter) are arrangements of a small number of elements.**
7. **Distinguish between physical and chemical changes.**
8. **Understand that energy exists in different forms, can be transformed, and is neither created nor destroyed.**
9. **Describe sound and light in terms of the properties of waves.**
10. **Describe the relationship between forces and motion with regard to Newton's laws.**

Life Science

11. **Describe the parts and systems of living things and relate them to need, function and classification.**
12. **Recognize that the traits of an individual organism are a combination of inherited traits and acquired traits.**
13. **Identify both adaptation and natural selection as processes that have resulted in the diversity of plant and animal life.**
14. **Describe relationships in ecosystems among organisms and between organisms and their environments.**

This section of the report contains the following for each indicator:

- explanation of how the indicator relates to success in college-preparatory laboratory science;
- guidance for teaching the indicator;
- a launch activity to encourage an inquiry-based lesson;
- the *Benchmark Proficiency Progression* chart;
- the proficiency level *Learning Activities and Applications*; and
- the *Proficiency Level Illustrations* of assessment items.

As stated earlier, most of the *Proficiency Level Illustrations* are from two outside sources, but some were written by the panel for this report. In most cases, the items from the outside sources appear as originally published, but in some cases, multiple-choice items have been converted to open-ended items. These cases are noted. The two outside sources are

- the National Assessment of Education Progress (NAEP), Eighth Grade Science Assessment, 1996 and 2000, National Center for Education Statistics, U.S. Department of Education; and
- the Third International Mathematics and Science Study (TIMSS), 1995 and 1999 Reports, International Association for the Evaluation of Educational Achievement (IEA).

1 *Earth/Space Science*
Describe processes that alter Earth's surface.

During the middle grades, students learn that evidence for the changes in Earth's surface can be found in the layers of rocks, erosion, weathering, soil deposition, plate tectonics, volcanic activity and earthquakes. Upon leaving the middle grades students understand the constancy of Earth's changes and can describe the causes, effects and time frames of the major types of change (weathering, rock cycle, erosion, earthquakes, volcanoes and plate tectonics). Knowing and understanding how local geologic conditions relate to the types of changes that have occurred over time, students can apply this knowledge to advanced physical and chemical concepts in high school.

Learning about the major types of physical and geologic changes that occur over time is important in understanding that various forces are constantly at work shaping and changing Earth's surface, and that these internal and external forces build its surface up and wear it down. This understanding is the precursor to learning more in-depth physical and earth science content.

For labs and other hands-on activities teachers can use instructional aids such as diagrams, topographical maps, rock specimens, stream tables and computer programs. Use of concrete materials such as samples of sand from different locales, rock chips and topographic maps helps students grasp abstract concepts and understand the forces that wear down and change Earth's surface. Teachers can provide students with opportunities to model such things as stream and beach erosion, plate tectonics and to differentiate rock types. Students need opportunities to investigate local geology to focus their attention on the rock cycle and changes over time. If there are no rocks in the local area, students can brainstorm reasons why and follow up with research.

Launch

While scoping out a new trail for an overnight hike, you notice a very large and most unusual depression in the surface of the trail. What is it? Will this cause a change in your route? What will you do? (Teachers can supply more specific geographic descriptions for particular regions.)

THINK!!!

1. Why do you think this may not be a normal formation? **(Compare/contrast)**
2. Do you have any ideas about what it is? **(Brainstorm ideas)**
3. Have you ever seen anything like it before? Can it be dangerous to hikers? **(Assess prior knowledge)**
4. How will you discover what it is? **(Research)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
▪ Examine local areas for evidence of erosion and weathering.	▪ Investigate and calculate the damage to surface areas from erosion and weathering.	▪ Design strategies for reducing erosion and weathering on specific surfaces.
▪ Observe and identify various components in soil samples.	▪ Find and record various examples of soil deposition.	▪ Predict how local geology will change over time.
▪ Use a classification chart listing the characteristics of rocks.	▪ Create a classification chart to identify types of rocks.	▪ Determine the relationship between temperature and pressure as they relate to the rock cycle.
▪ Construct a model of tectonic plates detailing their possible movements.	▪ Generate the steps in and the impact created by movement of tectonic plates.	▪ Predict future earthquakes and volcanoes using historical and current data about tectonic plates to support conclusions.

Learning Activities and Applications

- Given three core samples of soil, students identify the texture and composition of the different soils, estimate the percentage of each type of component and construct representative graphs. They present their findings to the class. **(Basic)**
- Students select soil from at least three different sites on campus or from home, examine the components and research the possible origin of components in each sample. Students test the three samples for water retention and compressibility, draw conclusions and present findings to the class. **(Proficient)**
- Each student group designs an investigation to assess the characteristics of soil and establish the type or combination of types that provides the best structural foundation for a building. They present and defend their findings to the class. **(Advanced)**

- Students use a variety of materials such as modeling clay, wood, paper or other materials to demonstrate the basic movements of tectonic plates. They explain how earthquake, volcanic formation or other activities are possible on the plates. **(Basic)**
- Each student group researches the environmental changes that can be detected before a volcanic eruption or earthquake. Students record the information, make predictions and discuss how warning systems can be provided. **(Proficient)**
- Using geological maps of the world, students collect and prioritize pertinent information about tectonic plate movement. They predict areas of the world where earthquakes and volcanoes are most likely to occur. News articles about recent earthquakes and volcanoes can be used in their research. They present findings to the class and defend the reasons for each. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 1

Basic

1-1 Which BEST describes the movement of the plates that make up Earth's surface over millions of years?

(A) They moved for millions of years but have now stopped.

(B) They stayed the same for millions of years but are now moving.

(C) They have been continually moving.

(D) They have never moved.

(TIMSS)

Proficient

1-2 Using the model of the rock cycle, within the next 100 years, what will happen to small particles of rock flowing in a river?

(A) They become part of Earth's mantle.

(B) They are found in lava flowing from a volcano.

(C) They make up metamorphic rock.

(D) They become sedimentary rock.

(Panel)

Advanced

1-3 If the locations of earthquakes over the past ten years were plotted on a world map, which of the following would be observed?

(A) Earthquakes occur with the same frequency everywhere on Earth.

(B) Earthquakes generally occur along the edges of tectonic plates.

(C) Earthquakes most frequently occur near the middle of continents.

(D) Earthquakes do not seem to occur in any consistent pattern.

(NAEP)

2 *Earth/Space Science*
Know that rocks and fossils provide important evidence of how the physical earth and biological systems have changed over long periods of time.

During the middle grades students learn that the history of Earth is measured in geologic time, and that major changes on Earth and in living things occurred during each geologic time period. Middle grades teachers can take advantage of the natural interest students have in rocks and fossils to learn how fossils are formed in different strata of rocks with younger layers deposited over older sediment. Also, students learn how the layering of rocks and the positions of different fossils can be used to make inferences about changes on Earth and in plants and animals and other organisms over time. Scientists study fossils, rocks and conditions such as salt deposits and sedimentary rock formations to provide clues about the mineral deposits and changes in climate over time. Students gain appreciation of scientific research and how scientists learn about geological changes.

By learning about the composition of rocks and the physical and chemical properties of minerals composing the rocks, students build a foundation for further study in high school college-preparatory science courses. By using chemical properties such as a mineral's reaction to acids and the physical properties of hardness, luster, cleavage and color, students categorize and classify rocks and minerals, thus preparing them for advanced study in chemistry and physics.

Launch

Your eighth grade science teacher asks everyone to bring a sample of a fossil to class. Your friend, Cassandra, shows everyone a "fossil" that has no recognizable shape or form. Cassandra argues that it has been in her family for a long time and that it is a real fossil. You need to help discover the truth about her "fossil."

THINK!!!

1. Have you ever seen anything like this before? **(Prior knowledge)**
2. What determines if something is a fossil? **(Prior knowledge)**
3. Do you think Cassandra is correct or incorrect? Explain. **(Brainstorming)**
4. What specific tests can you use to determine the validity of her claim? **(Research)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
■ Observe the characteristics of fossils using a variety of samples.	■ Compare fossil samples to a chart of index fossils and estimate their geologic ages.	■ Order and display fossil samples on a timeline and explain the presence of gaps in the fossil record.
■ Demonstrate the half-life of isotopes using a model.	■ Simulate the steps used in radioactive dating.	■ Create a chart comparing radioactive decay to another event.
■ Develop a mineral identification table using specific characteristics.	■ Determine which characteristics are most reliable for identifying minerals.	■ Develop a mineral identification table that includes three additional characteristics of minerals.

Learning Activities and Applications

- Assign students a sample of 10 fossils and ask them to make observations and predictions related to age, formation and type of fossil. They present their observations and conclusions to the class. **(Basic)**
- Provide modeling clay or Plaster of Paris for each student to create a fossil from a specific time period. Have students use reference charts and research materials to determine the time period, major events and conditions under which similar fossils were formed. They share their fossils and information with the class. **(Proficient)**
- Provide students with models or photographs of vestigial, homologous and analogous structures found in modern organisms. Students compare the models and photographs to structures in the ancestors of each species. They research the changes and possible reasons for the changes and discuss how these may affect future fossil records. Students summarize, present and defend their findings to the class. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 2

Basic

2-1 Explain why fossils of fish can be found on dry land and on mountains.

(Panel)

2-2 For which of the following have fossils been found

- (A) plants
- (B) dinosaurs
- (C) eggs
- (D) bacteria
- (E) all of the above

(Panel)

Proficient

2-3 Rocks in streambeds constantly move about in water and scrape against each other and the streambed. Explain how you would simulate the fact that the longer the rocks are in the stream, the more they tumble and change in size and shape.

(Panel)

2-4 Fossils of trilobites and other organisms found near the top of a mountain in New York state provide evidence that this area has most likely undergone

- (A) crustal plate collision causing metamorphism.
- (B) seafloor spreading caused by a volcano.
- (C) uplift from crustal plate movement.
- (D) recent flooding.
- (E) all of the above

(Panel)

Advanced

2-5 A group of scientists claims that an area of land currently 2,000 feet above sea level was once covered by ocean. Another group of scientists claims that two areas currently on separate continents were once connected as part of a larger landmass.

Describe the evidence you would look for in each of the two areas to support or defend each group's claim. Explain the major differences in the types of evidence you would collect from each area.

(Panel)

3 *Earth/Space Science*

Describe the position and movement of the major bodies of the solar system and current scientific theories of their origin.

The middle grades students' first introduction to physics often comes through study of the solar system. This study sets the stage for understanding and applying the laws of physics. By the end of the eighth grade, students will understand that the solar system is an ever-changing system of fast-moving bodies with vast distances between them and is governed by the laws of physics. While scientists know that the sun is the center of our solar system and other information about each of the planets, theories about the origin of the solar system are not as conclusive. Because the planets and other objects are at such great distances from the sun and each other, astronomers use the laws of physics to determine their positions and astronomical units to indicate distances. The balance between the sun's gravitational pull and each planet's own motion determines the pathway around the sun.

Understanding rotation, axis of rotation and revolution prepares students for recognizing the importance of the sun's gravitational pull on all objects in the solar system and comprehending the sun's impact on phases of the moon, tides, seasons and other natural phenomena occurring on Earth. Making quantitative observations about the sizes of the planets and the distances in our solar system aids students' understanding of scale, ratio, proportion and the usefulness of scientific and exponential notation.

Teachers can use models and simulations of the planets and solar system to describe the pathways and rotations of the planets and backyard telescopes to engage students in learning more about our solar system. Trips to local observatories, natural history museums and planetariums provide real-life experiences for students.

Launch

While your astronomy club is observing the night sky with a telescope, you and another club member observe a strange object in orbit between Earth and Mars. It is not located on any of your star charts. You think it is an undiscovered planet.

THINK!!!

1. What are the possibilities of what it could be? **(Prior knowledge)**
2. What characteristics are necessary for it to be classified as a planet? A meteor? A UFO? **(Research)**
3. What would you name it and why? **(Creative thinking)**
4. How will you discover the truth? **(Research)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
■ Describe and demonstrate the tilt of Earth as the cause of the seasons.	■ Diagram and use models to explain the position of the sun, Earth and the moon during the four seasons.	■ Use models to compare the current tilt of Earth to prescribed changes and predict the impact.
■ Demonstrate how a theory is developed and relate it to the universe.	■ Research and compare theories about the origin of the universe.	■ Present and defend arguments to justify your opinion of the origin of the universe.
■ Model the movement of objects in the solar system.	■ Demonstrate the movements of objects in the solar system relating to periods of time. (year, month, day)	■ Contrast the differences in a day on Earth and on another planet (Mars).

Learning Activities and Applications

- Given protractors, clay and other materials, students construct and label models showing the tilt of Earth's axis and its orientation to the sun during each season in their hometown. They present their findings to the class. **(Basic)**
- Given protractors, clay and other materials, students construct and label models showing the current tilt of Earth's axis and its orientation to the sun during one season in their hometown and models showing what that season would be like if there were no tilt to Earth's axis. They explain their models to the class. **(Proficient)**
- Students design models comparing the current temperature variation during the four seasons in their hometown to the temperature variations during the four seasons if the tilt of Earth was increased by 15 degrees. **(Advanced)**

- Given 10 photographs of various solar system bodies, students classify the pictures into groups based on similarities and differences and explain their reasoning. **(Basic)**
- Each student group develops a list of the criteria for classifying objects in the solar system such as planets, comets and satellites. They exchange lists with other groups and practice classifying objects provided by the teacher. **(Proficient)**
- Given one type of object (a picture or word written on index cards) such as moons or asteroids found in our solar system, students show on charts the location of all such objects currently identified in our solar system. They use appropriate scales and display their results. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 3

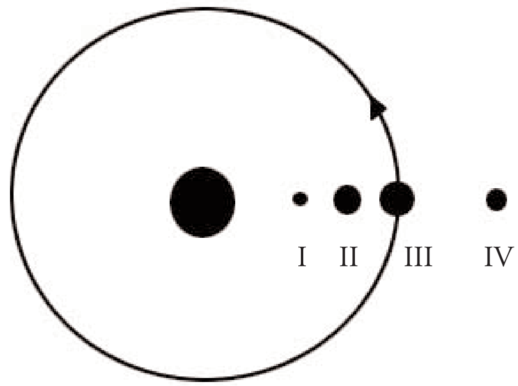
Basic

3-1 Complete a simple model of the solar system by drawing the paths that Mercury, Venus and Mars take as they move around the Sun. Draw arrows on the paths to show the direction in which each moves.

(NAEP)

Proficient

The picture to the right illustrates a simplified model of part of the Solar System. The Sun and the four planets closest to the Sun are represented by the shaded figures. The Earth's orbit (the path that it takes as it moves around the Sun) is represented by the large circle and the arrow on this circle shows the direction in which the Earth moves.



Planets

I Mercury
II Venus
III Earth
IV Mars

For items **3-2** and **3-3** use the diagram above.

3-2 State two ways, other than the planets being in the correct order, in which this simple model is like the real Solar System.

(NAEP)

3-3 Explain how the diagram should be changed to show more correctly the relative sizes of the Sun and the Earth.

(NAEP)

3-4 According to scientific theory, as the Solar System formed, matter in the solar nebula came together to form planets. The force most responsible for these formations was

(A) gravitational (B) electrical (C) magnetic (D) nuclear

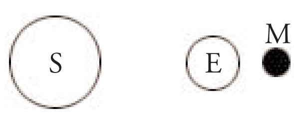
(NAEP)

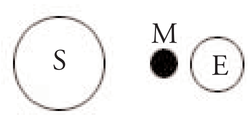
Advanced

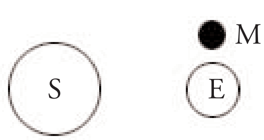
3-5 If you measured your shadow at noon during the summer and at noon during the winter, would the measurements be the same or would they be different? Explain your answer.

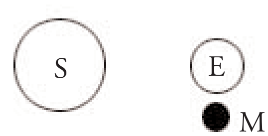
(NAEP)

3-6 In which relative position of the Sun (S), Earth (E), and the Moon (M) is a lunar eclipse most likely to happen?

(A)


(C)


(B)


(D)


(NAEP)

4 *Earth/Space Science*
Describe causes of weather events and changes in climate.

Upon leaving the middle grades students are able to differentiate between weather and climate, describe the causes of weather and climate, relate Earth's rotation to the movement of air masses, describe wind systems, identify weather fronts, analyze a weather map, classify climates, explain why climates change, and identify how humans impact climate.

Climate and weather are essential understandings for further study of science phenomena. Surface conditions, air masses, high- and low-pressure systems, fronts and temperature changes directly affect our lives. Understanding these conditions helps students predict and plan for their own activities and are the kinds of skills needed in college-preparatory high school classes. For labs and other hands-on activities teachers can use pictures, diagrams, weather maps and weather instruments, such as thermometers, anemometers and rain gauges. Students need opportunities to model cloud formation, the greenhouse effect, wind generation and the angle of the sun's rays relative to intensity. Students can investigate and chart local weather and climate over time and use data to make forecasts.

Launch

A relative living in Venice, Italy e-mails you and asks for help in choosing stylish new summer clothing. She explains about changes in the weather during the last five years and insists she no longer needs to wear winter clothes.

THINK!!!

1. What do you think is happening? **(Brainstorming)**
2. Are there other places where weather and/or climate are changing? **(Research)**
3. What is the current temperature in Venice and how is it different from normal? **(Research)**
4. How will you discover the real story? **(Research)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
■ Compare the different aspects of weather and climate in the local area. ■ Chart weather features on a weather map of the area.	■ Explain the relationship between climate and the variables that create it. ■ By summarizing information from a weather map and collected data, predict weather for the local area.	■ Defend the accusation that humans have negatively impacted world climate. ■ Design a geolab environment that produces favorable weather conditions every day for a month.

Learning Activities and Applications

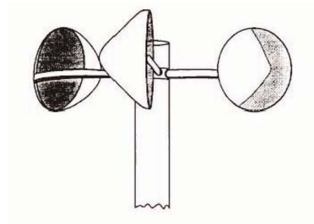
- Using newspaper or television weather maps as a guide, students analyze weather patterns for a specific locale. They design current weather maps that include the major weather symbols arranged in a realistic weather pattern. They assume the role of TV weather forecasters as they explain their maps to the class. **(Basic)**
- After charting and analyzing local weather data and predictions over a two- or three-week period with the class, student groups use weather maps from newspapers or the Internet to chart and predict weather in a specific area over a period of several days. They compare their forecasts with the actual weather for that period of time and present their results to the class. **(Proficient)**
- Students research and write position papers on changes in world climate and its human impact. They send and/or present their papers to a local environmental group. **(Advanced)**

- Using purchased or student-made weather instruments, students collect and chart specific weather data. They record and discuss changes over a two- to three-week period. **(Basic)**
- Students locate major climate zones on world maps and indicate factors that create the climate. Each group researches and evaluates a particular area and determines the pros and cons and the challenges of living in such an area. They present the information to the class. **(Proficient)**
- Each student group designs an investigation and constructs a model geolab that simulates such factors as plant/animal maintenance, outside versus inside weather changes and concentrations of oxygen and carbon dioxide within the GeoLab. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 4

Basic

4-1 The instrument shown is used to measure:



(A) wind direction
(B) wind speed
(C) air pressure
(D) relative humidity

(NAEP)

4-2 Based on the weather data in the table, on which day was snowfall most likely to have occurred?

(A) Monday (B) Tuesday (C) Wednesday (D) Thursday

	Monday	Tuesday	Wednesday	Thursday	Friday
High Temperature (°F)	43	50	42	53	60
Low Temperature (°F)	28	38	28	39	45
Precipitation	0.0	1.0	1.5	0.0	1.6
Average Wind Speed (mph)	15	1.0	7	10	10

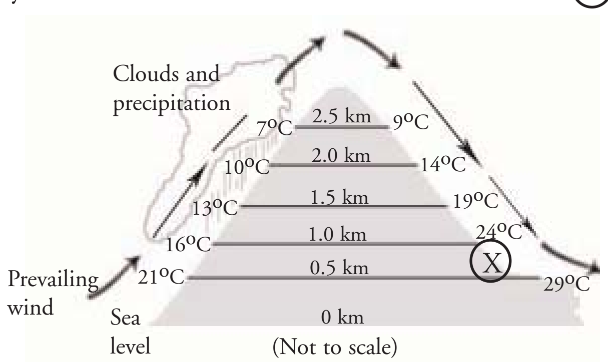
(NAEP)

Proficient

4-3 The diagram below shows a mountain. The prevailing wind direction and average air temperatures at different elevations on both sides of the mountain are indicated.

Which feature is probably located at the base of the mountain at location (X)?

(A) a dry region
(B) a jungle
(C) a glacier
(D) a large lake
(E) a rain forest

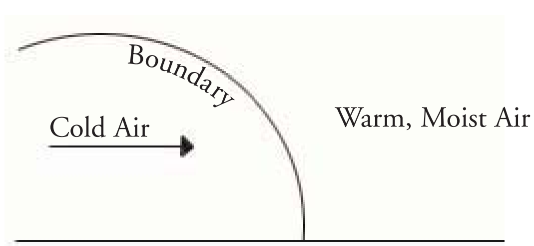


(TIMSS)

Advanced

4-4 The diagram below shows the boundary between a cold air mass and a warm, moist air mass.

Describe how the interaction of the cold air and the warm air can cause rain at the boundary.



(NAEP)

5 *Earth/Space Science*
Describe the water cycle.

Middle grades students are expected to understand that the water cycle is a dynamic process during which water is transformed through the gas, liquid, and sometimes solid phases, but is neither created nor destroyed. The ability to understand water and the water cycle is essential if students are to comprehend ideas such as acidity, alkalinity, ionization, titration and other chemical and physical concepts essential to succeeding in chemistry, physics and earth science in high school.

Upon leaving the middle grades, students can draw, label and understand a diagram of the water cycle and explain the transformations (evaporation, condensation, transpiration and precipitation) in terms of energy, temperature and polarity. Students can evaluate the effects of climate and human development upon the local and global water cycle and understand the role of water in maintaining life on Earth.

Students can investigate water and the water cycle with simple materials. Evaporation rates can be determined over time with containers of water positioned at various locations. Small magnets can be used to illustrate the polar nature of water molecules. Other instructional aids such as pictures and diagrams illustrate the hydrologic cycle, and mini-water cycles using jars, terrariums or other clear containers with soil, water and plants assist students with explaining, predicting and connecting classroom activities to complex cycles in nature.

Launch

Your family lives on a hillside in a mountainous farming community close to the ocean. A cool, moist climate produces perfect growing conditions for many farms in the area. A developer has targeted the mountain range west of your community and intends to flatten many acres to build a large theme park. Many jobs will result.

THINK!!!

1. What is the importance of a mountain range on weather and (or climate) in an area? **(Brainstorming)**
2. What impact, if any, will the change in the mountain range have on local conditions? **(Prediction)**
3. What data would be most significant to determine change? **(Investigation)**
4. What safeguards are possible to prevent potential damage? **(Research)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
■ Describe the water cycle in nature.	■ Analyze the water cycle in terms of energy requirements.	■ Relate the structure of the water molecule to the water cycle. (polarity)
■ Demonstrate how changing conditions affect a cycle.	■ Demonstrate the relationship between climate and the water cycle.	■ Investigate the impact of human activity on the water cycle.

Learning Activities and Applications

- Given clear containers, soil, water and plants, student groups demonstrate the basic processes of the water cycle. Each group presents its model to the class. **(Basic)**
- Student groups use materials of their choice to construct models of the water cycle in a specific biome (desert, temperate grassland, savanna, tropical, deciduous, tundra). Each group collects and records quantitative data such as temperature and precipitation amounts and makes qualitative observations and presents its model to the class. **(Proficient)**
- Student groups research the possible environmental impact on the area's water cycle of constructing a large shopping mall. Each group designs a new shopping mall that is environmentally friendly and reduces the impact on an area's water cycle as much as possible. Materials and design choices are justified by research. **(Advanced)**

- Students use balloons, clay or other materials to show the basic structure of a water molecule. Each student imagines that he/she is a water molecule near the surface of a lake that evaporates into the air. They use their models to describe what they would feel and see. **(Basic)**
- Using materials of their choice, students create several models of a water molecule. They use their models to describe what happens throughout the water cycle and describe what would happen if a water molecule was not a polar molecule. **(Proficient)**
- Students research the properties of water. Each student group designs a model, display or activity that illustrates one of the unique properties of water: universal solvent, adheres and is cohesive, resists change of state, less dense as ice than as liquid, and ionizes or dissociates. They present their results to the class. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 5

Basic

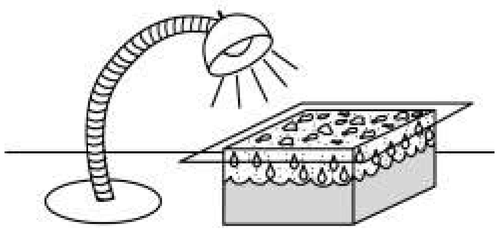
5-1 After a raindrop hits the ground, describe a path it (or water molecules within it) might take to fall as rain again.

(Panel)

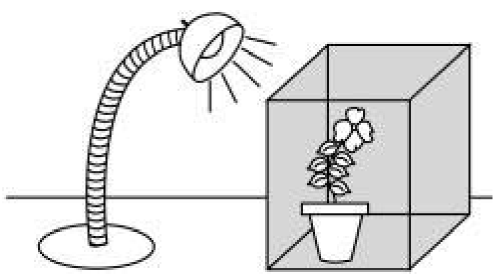
Proficient

5-2 Which of the following would be the best model to show the interactions between water and the Sun's heat energy in cycles of precipitation?

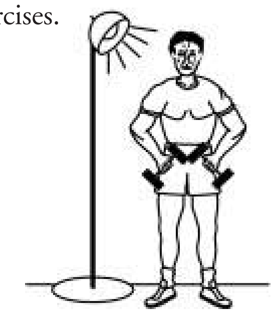
(A) A light shines on an aquarium covered with glass, and water droplets form on the inside of the glass.



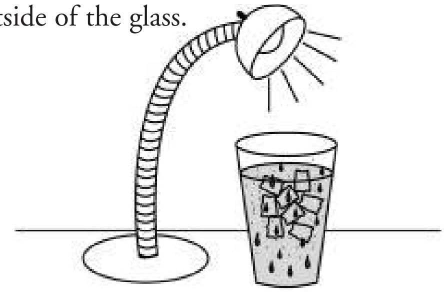
(B) A light shines on a closed cardboard box containing a plant.



(C) A light shines on a man's face. Droplets of sweat form on his face as he exercises.



(D) A light shines on a glass of iced tea. Water droplets form on the outside of the glass.



(NAEP)

5-3 Draw a diagram to show how the water that falls as rain in one place may come from another place that is far away.

(TIMSS)

Advanced

5-4 According to the water cycle, water is neither created nor destroyed; it is simply re-cycled through different forms. Does the fact that some areas experience water shortages prove the water cycle to be incorrect? Provide at least two reasons to support your answer.

(Panel)

About the Sample Scientific Investigations

Each sample investigation described in this report begins with a scenario followed by suggested activities at the Basic, Proficient and Advanced levels. Students can conduct investigations individually, in groups or as an entire class. Before beginning an investigation, students should discuss their hypotheses and expectations of results by posing the following types of questions:

- What do you think will happen?
- If a claim or a hypothesis is presented, do you agree or disagree? Why?
- How is the subject of the investigation related to what you think might happen?

After the investigations, students present, discuss and defend their findings to their classmates and evaluate other students' thinking and analyses.

As students conduct investigations and analyze findings, they often uncover questions and concepts that are beyond the scope of the middle grades science curriculum. **The fact that students might ask questions beyond the scope of the curriculum is not a reason for avoiding an investigation.** These questions can be a source of rich discussions about possible research designs and measurement.

Sample Investigation* for Content Indicator 5: Describe the water cycle.

Water, Water Everywhere

Scenario After learning about the water cycle and making models of it, one of your classmates states that because both the textbook and the teacher say that "sunlight causes water to evaporate," then the water cycle cannot happen in winter and at the North and South Poles.

1. Design a scientific investigation.

Provide students with this question — under what conditions will water evaporate in wintry conditions?

- Students review the following investigations and choose the one they think is the best to answer the question. **(Basic)**
  - Place very cold water in a container in your classroom and then check once each day for a week to see how much water is left.
  - Place very cold water in a container in the refrigerator and then check once each day for a week to see how much water is left.
  - Wait until winter, then place water in a container outside and check once each day for a week to see how much is left.
- Based on the classmate's conclusion in the scenario, students identify a related question and design an investigation to test it. Their designs may involve placing several sizes of graduated cylinders or containers with equal amounts of water in cold and dark conditions. Students monitor changes in the amount of water and temperature at regular intervals over a period of several days. **(Proficient)**
- During discussions and brainstorming about the scenario, one student argues that evaporation does happen in winter and at the poles, but that it happens much more slowly. Based on this claim, students identify related questions and design investigations to test one of them. Designs should include comparing evaporation rates of water placed in conditions of different temperatures and amounts of sunlight. Students use thermometers, liquid measures and a variety of graduated and non-graduated containers. **(Advanced)**

* A sample rubric for evaluating student scientific investigations is on page 13.

2. Conduct a scientific investigation.

- After predicting their results, students follow the steps of the investigation they chose and record their observations. Students use thermometers and graduated cylinders in one size to conduct the investigation they chose. **(Basic)**
- After designing their own investigation, writing a hypothesis and predicting their results, students determine whether the percent change is the same or different for the various containers. Students record their measurements (data) at regular intervals for the various sizes of graduated cylinders or containers. **(Proficient)**
- After designing their own investigation, writing a hypothesis and predicting their results, students determine whether the percent change is the same or different for the various containers. Students record their measurements (data) at regular intervals for a variety of graduated and non-graduated containers. Provided with hypothetical sets of data, students determine which sets are plausible. Students use weather data and charts to explore various relationships between such factors as precipitation, temperature, hours of daylight and relative humidity. **(Advanced)**

3. Analyze the findings of a scientific investigation.

Students review the data to formulate their conclusions and answer the following questions:

- Based on your results, how would you respond to your classmate's statement about the evaporation of water in cold temperatures? **(Basic)**
- How do the results compare with your original hypothesis? **(Basic)**
- Are there other possible explanations for your results? **(Proficient)**

In addition to the question at the Proficient level, students also answer the following:

- Identify and describe any variables that might have affected your results. **(Advanced)**

4. Communicate and defend findings.

- Students answer a series of short-answer questions about their investigation, write a brief summary and give a brief oral report. They create simple graphs to show the changes observed in the water level. **(Basic)**
- Students write a summary of their investigation. The summary includes a hypothesis, a step-by-step description of the design of their investigation, and how their investigation relates to the original hypothesis. They graph the data showing the changes in the water level over time. Based on the data, they predict what they would expect to happen over a longer period of time. **(Proficient)**
- In addition to the summary described at the Proficient level, students graph their results to show the comparison of the different conditions examined. They identify variables and possible sources of error. **(Advanced)**

5. Evaluate other scientific investigations and apply results.

Students review their classmates' reports and answer the following questions:

- How do their investigations and conclusions differ from yours? If so, why? **(Basic)**
- If you were to do this investigation again, what would you do differently? **(Basic)**
- If their conclusions are different from yours, how are their conclusions supported by their experimental designs? **(Proficient)**
- If you had problems with your design, how did you overcome them? Explain. **(Proficient)**
- How would you design another investigation that creates conditions closer to the conditions in winter and at the Poles? **(Proficient)**
- Looking at some of the problems your classmates encountered, what are some ways to improve their experimental design? **(Advanced)**
- Create a story about what happens to a beaker of water traveling on board a space shuttle or research the impact of low gravity on the molecular structure of a water molecule at 4°C. **(Advanced)**

6 *Physical Science*
Explain that all substances (matter) are arrangements of a small number of elements.

In the middle grades, students understand the basic physical properties of *matter* as anything that has mass and takes up space and that *elements* are substances that contain only one kind of atom and cannot be broken down into simpler substances by ordinary physical or chemical means. Upon leaving the middle grades students can define matter in terms of its general physical properties, understand that a substance's physical properties are unique to that substance, can differentiate between *substances and mixtures* and can define elements in terms of their *atomic structures*.

Understanding matter and atomic structure is essential to understanding chemistry and physics. Middle grades students need experiences measuring, determining and comparing the physical properties of matter (states or phases of matter, color, luster, melting point, boiling point, mass, odor, hardness, density, conductivity, magnetism and solubility) and determining variables that affect the rate of change from one state to another.

Middle grades students need opportunities to investigate the atomic structure of at least the most common elements, and to develop and use strategies for representing them graphically. Instructional aids such as pictures, models, diagrams and video clips help students visualize these concepts. Common substances such as salt, sugar and cereal encourage students to identify components and separate mixtures. Appropriate laboratory equipment such as beakers, thermometers, burners, etc. will provide students with opportunities to collect, graph and present quantitative data.

Launch

While watching a popular science fiction movie, a man is transported to another place by "rearranging and sending his atoms and molecules." You wonder if objects can be changed into a different form and transmitted to other places. Is that really possible? Can atoms and molecules be rearranged and transported? In real life, is there technology that can do this?

THINK!!!

1. Are the building blocks of all substances the same? **(Prior knowledge)**
2. Can objects change shape and form and be transmitted? **(Research)**
3. Are there real-life examples of data and object transmission? **(Brainstorming)**
4. Give examples of how science and science fiction are merging in this area. **(Research)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
■ Provide examples of elements, compounds, solutions and mixtures.	■ Describe and demonstrate how mixtures can be separated.	■ Explain the relationships among solutions, mixtures, solutes and solvents.
■ Investigate ways to change substances from one state to another (phase change).	■ Investigate ways to control the rate of change from one state to another.	■ Relate phase change to real-world experiences (Use of antifreeze in asphalt and/or coolants).

Learning Activities and Applications

- Given filter paper, black felt-tip pens, water, beakers and paper clips, students separate black ink into its component colors and describe the process and results. **(Basic)**
- Given filter paper, a variety of black pens (permanent and water-soluble), water, solvent or nail polish remover, safety goggles, gloves, beakers and paper clips, students separate different types of black ink into their various colors. They describe the process and discuss the necessity of various solvents. **(Proficient)**
- Given filter paper, a variety of black pens, water, solvent, safety goggles, gloves, beakers and paper clips, students separate black ink into its component colors. They describe the process and discuss the necessity of various solvents. Students calculate the ratio of each color by dividing the distance the color traveled by the distance the solvent traveled. They record and present findings. **(Advanced)**

- Given two different materials (copper wire, aluminum wire or water and mineral oil), students compare and contrast their physical properties (color, melting point, boiling point, odor, density, conductivity, magnetism and solubility). They present findings to the class. **(Basic)**
- Given an unknown substance (copper, aluminum or brass), students identify the substance based on physical properties and present oral and written reports to the class. **(Proficient)**
- Students investigate how mixing substances impacts their physical properties such as phase changes. (Example: How does the addition of sodium chloride affect the freezing or boiling point of water?) They present their results to the class. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 6

Basic

6-1 Which of the following is NOT a pure substance?

(A) table salt (B) water (C) air (D) aluminum

(Panel)

6-2 Which of the following is NOT a mixture?

(A) air (B) blood (C) orange juice (D) salt

(TIMSS)

Proficient

6-3 All of the following would be helpful in separating a mixture of sand and salt EXCEPT

(A) a magnet (B) a glass cup (C) a filter paper and water (D) water

(NAEP)

Advanced

6-4 Which mass is greater — liter of water or a liter of methanol? Explain your answer in terms of density and make a diagram to show molecular distribution.

(Panel)

7 *Physical Science*
Distinguish between physical and chemical changes.

Upon leaving the middle grades students can differentiate between physical changes and chemical changes, and demonstrate examples of these changes. A physical change occurs when a substance changes form but remains the same substance. A chemical change occurs when a substance changes into a new substance with different properties. Students understand that while matter cannot be created or destroyed, the form of matter can be changed.

Students can understand that chemical changes, or reactions, involve changes in chemical bonding (molecular or covalent, ionic and metallic) and that certain variables affect the rates of these reactions. Students need experiences in controlling the rates of reactions and predicting which new substances or products will be produced. It is helpful if students have already learned to write simple formulas for compounds.

Students need experiences in navigating through the periodic table as preparation for high school chemistry and physics. Students can understand that few elements are found in their pure form, all elements have unique characteristics and that elements are grouped on the periodic table according to similar properties. These include highly reactive and less reactive metals, highly reactive nonmetals (e.g., chlorine, fluorine, oxygen) and some almost completely nonreactive gases (e.g., neon, helium). Students can identify metallic and nonmetallic elements by their positions on the table and be able to predict and name compounds formed when a metal and non-metal react. In addition to the periodic table, instructional aids (e.g., pictures, models, diagrams) and appropriate laboratory equipment (e.g., beakers, thermometers, burners), can provide students with opportunities to collect, graph and present data.

Launch

Your new electronic game board accidentally fell onto a hot stovetop and several sections of the wires and circuitry melted and fused together into one big blob. You know that the wires and the circuits have changed, but can they be changed back?

THINK!!!

1. Describe what the “blob” might look like. **(Brainstorming)**
2. What other examples have you seen when this happened? **(Prior knowledge)**
3. What are the possibilities of getting the wires organized and working again? **(Investigation)**
4. What determines if an object can be returned to its original shape? **(Research)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
■ Demonstrate molecular, ionic and metallic bonding.	■ Demonstrate how position on the periodic table can predict bond formation. (first 18 elements)	■ Predict periodic trends of elements. (19 and higher.)
■ Demonstrate a chemical change and relate it to bonding (reactants and products).	■ Analyze a chemical change in terms of energy requirements and conservation of matter.	■ Develop and recommend techniques for controlling the rate of a chemical reaction.

Learning Activities and Applications

- Students observe a melting ice cube and explain if the change is reversible. Students then compare the melting ice cube to steel wool rusting and explain if that change is reversible. They present their findings to the class. **(Basic)**
- Students conduct a chemical change, such as the burning of sugar, and explain the change to the class in terms of atomic, molecular and substance changes. **(Proficient)**
- Presented with examples of an unwanted physical or chemical change such as water freezing in a car radiator or the rusting of a car body, students propose ways to control or prevent the change and explain why each would be successful. **(Advanced)**

- Given an iron nail and a beaker of water (galvanized nail and water or copper and water) students investigate and describe any chemical change in terms of physical properties. They present their findings to the class. **(Basic)**
- Each student group designs and conducts an investigation that controls the rate of a chemical reaction (steel wool, Alka Seltzer). They record, summarize and present their findings to class. **(Proficient)**
- Each student group designs an investigation into the formation of rust from iron and oxygen. They describe the change in terms of the properties of the reactants and product, and the energy requirements. Students predict the type of bond formation based on the position on the periodic table and present their findings to the class. **(Advanced)**

- After researching the ingredients found on the labels of five products, students predict whether each substance is an acid or a base. They use pH paper to test their predictions and present their findings to the class. **(Basic)**
- Students research the chemical formulas for five common household compounds and describe the uses of each. They present a list of the names for each element in the compound and explain the subscripts to the class. **(Proficient)**
- Students use models to show that many different kinds of compounds including real-life examples can form from carbon because of the arrangement of its electrons. They present their information orally and with graphics. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 7

Basic

7-1 Provide a common name for the changes described in the two situations and state whether each is a physical or chemical change.

(A) Water is heated on a stove causing the water to bubble and give off steam.

(B) A day after a bicycle rider rides in the rain, reddish orange spots appear on the bicycle chain and flake off when scratched.

(Panel)

Proficient

7-2 Imagine that you could put popcorn kernels into an airtight popcorn popper and measure the mass of the popper with the kernels. After the popcorn has popped, the mass of the popper and the popcorn will be:

(A) less than the original mass because popped corn is less dense than the kernels are

(B) equal to the original mass because the container is airtight

(C) greater than the original mass because the volume of the popped corn is greater than that of the kernels

(D) impossible to determine without weighing each piece of popcorn immediately

(NAEP)

Advanced

7-3 Rusting is the chemical combination of iron and oxygen. Paint applied to an iron surface prevents the iron from rusting. Write the chemical equation that produces rust and explain why paint interferes with this reaction.

(Panel)

8 *Physical Science*
Understand that energy exists in different forms, can be transformed and is neither created nor destroyed.

When students leave the middle grades, they can identify the various forms and sources of energy and explain energy conversions. Students will understand that energy is defined as the ability to do work and it can take many forms, such as heat, light, solar, mechanical, electrical and nuclear. Energy in use is called kinetic energy while stored energy is called potential energy. Students will discuss everyday energy conversions such as in cars, hair dryers and computers. They explain systems in terms of energy efficiency, particularly in terms of heat loss.

Energy conversion and energy consumption are necessary concepts for middle grades students to use when describing ways for collecting, transforming, transporting and harnessing energy and help students build a foundation for chemistry and physics.

Pictures, diagrams, electrical circuitry materials, electromagnets, thermometers, pulley systems and small solar panels are useful in helping students understand energy. Students need opportunities to model and investigate such things as parallel and series circuits, magnetism, heat loss during work, electrical generation, and conversion of light into electricity and energy sources. Using these materials and activities will develop skills for students to use during in-depth investigations in college-preparatory high school science courses.

Launch

After meeting your mother at her office and preparing to leave for home, there is a sudden loss of electricity throughout the city. You need to pick up your little brother from daycare and get home.

THINK!!!

1. What are your immediate thoughts? Concerns? **(Prior knowledge)**
2. Describe how you get from the ninth floor of the office to your home. **(Brainstorming)**
3. What changes did you observe as you made your way home? **(Investigation)**
4. Were you prepared for this occurrence? Why or why not? **(Research)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
■ Understand the units needed to calculate work and energy. ■ Demonstrate common sources, forms and conversions of energy.	■ Calculate work and energy. ■ Demonstrate and explain the generation of various forms of energy.	■ Calculate work, energy and power. ■ Analyze various situations and devices in terms of energy conversions and efficiency.

Learning Activities and Applications

- Given a list of 10 different actions (sawing a piece of wood, running an electric fan and sailing, etc.) students identify the original source of energy (as far back as possible) and classify the associated forms of energy. Students share their results with the class. **(Basic)**
- Given 10 examples or situations, students analyze and explain the energy conversions occurring in each. **(Proficient)**
- Students develop a procedure for determining the efficiency of a system, such as a pulley system, and collect data to support their conclusions. **(Advanced)**

- Using various types of cloth, string, toy cars and a ramp, students test different shapes of parachute design for slowing a moving car. **(Basic)**
- Using materials of their choice, each cooperative group designs and tests a parachute design for slowing a moving car. Groups chart and present findings to the class. **(Proficient)**
- Using materials of their choice, students research and design a parachute to slow a moving object. Students design the testing procedures for the class. Each group completes several trials and then presents its findings to the class. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 8

Basic

8-1 You are keeping a record of the temperature in your science classroom. When you start your investigation, the thermometer reads 34°C. The temperature in the classroom changes and is now 20°C. What happens to the mercury in the thermometer during this change in temperature?

(A) The mercury rises.
(B) The mercury falls.
(C) The mercury stays in the same place.

(Panel)

8-2 Music is playing from a boom box. What type of energy change is taking place?

(A) sound energy to electrical energy
(B) sound energy to chemical energy
(C) electrical energy to sound energy
(D) chemical energy to sound energy

(Panel)

Proficient

8-3 When operating, ordinary incandescent light bulbs produce a lot of heat in addition to light. Fluorescent light bulbs produce much less heat when operating. If you wanted to conserve electricity, which type of bulb should you use? Explain your answer.

(NAEP)

8-4 People get energy from the food they eat. Where does the energy stored in food come from?

(A) fertilizers
(B) the Sun
(C) vitamins
(D) the soil

(TIMSS)

Advanced

8-5 Which of the following represents the input/output energy forms for a stereo system?

	Input	Output
(A)	motion	sound only
(B)	motion	sound and heat only
(C)	electricity	motion and sound only
(D)	electricity	motion, sound and heat

(NAEP)

8-6 An insulated bottle keeps a cold liquid in the bottle cold by

(A) destroying any heat that enters the bottle.
(B) keeping cold energy within the bottle.
(C) trapping dissolved air in the liquid.
(D) slowing the transfer of heat into the bottle.

(NAEP)

9 *Physical Science*
Describe sound and light in terms of the properties of waves.

During the middle grades students need to build on their knowledge of frequency, wavelength and amplitude as characteristics of waves and understand that light and sound are forms of energy transmitted as waves. Students can investigate the speed and energy of sound and light and how they travel through matter or space. Students need to understand the impact a medium may have on how energy travels. Students can discuss that light is a part of the electromagnetic spectrum, a larger family of energy waves that travel through a vacuum at the speed of light. This understanding provides part of the foundation for higher-level science.

When students leave the middle grades, they can model sound waves and water waves and can relate them to energy transfer with respect to amplitude, frequency and wavelength. Students can distinguish between objects that emit light from those that reflect light and describe the dual nature of light — its particle and its wave character. Investigations and discussions about the various forms of energy prepare students for physics. Teachers can use instructional aids such as pictures, diagrams, computer simulations, vacuum pump/bell jars, mirrors, springs, ropes, lasers, diffraction gradients, ripple tanks, and prism and filmstrip projectors to prepare students for college-preparatory work in high school physics, chemistry and mathematics.

Launch

During a severe thunderstorm, you notice that your favorite radio station is interrupted by static. As you switch stations, you notice a difference in the reception for stations in your area. You try switching to AM, but the reception is worse. The best stations seem to be FM, but what about satellite radio?

THINK!!!

1. On your radio, which stations provide better reception? Why do you think this is true? **(Prior knowledge)**
2. Describe how AM, FM and satellite stations differ? **(Research)**
3. Are there ways to improve your radio's reception, even during severe weather? **(Research)**
4. Design a commercial to sell a new radio station. **(Creative thinking)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
■ Describe the electromagnetic spectrum.	■ Relate the electromagnetic spectrum to practical applications.	■ Draw conclusions about natural phenomena based on the electromagnetic spectrum.
■ Demonstrate the characteristics of sound and light waves.	■ Examine and relate characteristics of sound and light to wavelength, amplitude and frequency.	■ Research and summarize the effects of surfaces on light and sound reflection and absorption.
■ Explain the effect of different media substances on wave transmission.	■ Research why different energy forms require a medium.	■ Research product designs that impact sound transmission.

Learning Activities and Applications

- Given rubber bands, paper cups, paper clips and other materials, students develop an instrument capable of playing several notes. They demonstrate and explain how the sound is produced. **(Basic)**
- Students utilize rubber bands, stringed instruments or other objects to investigate and graphically display the relationship between pitch and frequency. This activity can be extended by having students use the same devices to investigate loudness. **(Proficient)**
- Each student group designs and conducts an investigation to determine the effects of environmental conditions such as humidity and temperature on the musical quality of stringed instruments. **(Advanced)**

- Using a light source and various reflective surfaces, student groups demonstrate and explain graphically what happens when light strikes each surface. **(Basic)**
- Using a light source and a prism or diffraction grating, students demonstrate and explain why portions of the electromagnetic spectrum are visible. **(Proficient)**
- Using various samples of glare-reducing materials such as sunglasses and window film for car windows, students design procedures to calculate the percentages of light that are transmitted through these objects. They discuss how the light is dispersed and transmitted. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 9

Basic

9-1 Gerald, standing at one end of a classroom, rings a bell. Lena, standing at the other end of the same room, hears essentially the same sound as Gerald. What causes the sound made by the bell?

(NAEP)

9-2 In the figure below, which of the following is the pathway of light that allows the child to see the ball?

(A) light bulb * child's eye * ball

(B) child's eyes * light bulb * ball

(C) ball * light bulb * child's eyes

(D) light bulb * ball * child's eyes

(NAEP)

Proficient

9-3 Which of the following colors has the longest wavelength?

(A) red (B) yellow (C) blue (D) violet

(Panel)

9-4 Name two reasons why a person would not get sunburned working all day inside a room well-lit with fluorescent light bulbs but might get sunburned wearing the same clothes in less than an hour outside?

(Panel)

Advanced

9-5 While practicing for a play, a student standing on the stage of a large, empty auditorium shouts loudly and hears her voice echo throughout the room. Later, the same student is on the stage of the same auditorium, which is now full of quiet people. The student shouts again, just as loudly. This time, however, she does not hear an echo. Explain why she hears an echo the first time and why she does not hear an echo the second time.

(NAEP)

9-6 James turns on a flashlight in his bedroom and shines it on his wall one meter away to produce a small circle of light. He then shines the flashlight on his ceiling two meters away to produce a larger circle of light.

a) Does more light reach the ceiling than the wall?

b) Explain your answer.

(TIMSS)

10 *Physical Science*
Describe the relationship between forces and motion with regard to Newton's laws.

During the middle grades students understand that a force is simply a push or a pull that can generate motion. They can explain Newton's Laws of Motion and the relationship between forces and motion and that laws relate to inertia, net forces and action/reaction forces.

Upon leaving the middle grades, students can describe, give examples and apply all three of Newton's Laws of Motion (Law of Inertia, Force is equal to mass times acceleration and Law of Action and Reaction). They can identify forces in a given situation such as frictional, mechanical (tensional, air resistance, applied and spring), gravitational, electrical and magnetic; and describe motion graphically. These concepts provide a foundation for higher-level work about forms of energy and energy transformation in physical science and physics in high school.

For labs and other hands-on activities, teachers can use instructional aids such as pictures, diagrams, balances, graph paper, stopwatches, computer simulations, rolling objects, inclined planes, photo gates, Newton scales and projectiles. Students need opportunities to model and investigate speed, acceleration and magnitudes of force, friction, projectile motion, and gravity. These are critical components in the study of physics that prepare students for high school physics courses.

Launch

Your science teacher presents the class with an interesting question — if there is a head-on collision in a car, is it better for the car to hit an object that is moving or is it better to hit an object that is stationary. During the discussion, several valid points are made for both sides.

THINK!!!

1. What determines the damage to a vehicle when it hits another object? **(Prior knowledge)**
2. How is the force different when two objects are moving as compared to one moving and one not moving? **(Research)**
3. Should vehicle crash tests include both examples? **(Investigation)**
4. Can Newton's laws help explain the resulting damage? **(Research)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
■ Demonstrate Newton's Three Laws of Motion.	■ Investigate the effect of varying masses and forces on motion.	■ Analyze and describe the relationship between speed and time.
■ Demonstrate what friction is and how to reduce it.	■ Investigate the most efficient friction-reducing substances.	■ Design and evaluate methods of reducing friction.

Learning Activities and Applications

- Using simple setups such as toy cars and ramps to put objects into motion, students observe, explore, measure and compare changes that allow the objects to travel farther, faster and for longer periods of time without additional force. They explain using graphics. **(Basic)**
- Students examine scooters, bicycles, inline skates and other mechanical devices for design features intended to reduce friction and air resistance and, where possible, measure and compare the effectiveness of these measures. They present their findings to the class. **(Proficient)**
- Each student group designs and conducts an investigation to determine ways to reduce friction in a moving object and determine how these reductions impact speed and/or the distance traveled. They present and defend their findings. **(Advanced)**

- Students identify and display five examples of force and motion in sports and describe each in terms of Newton's laws. **(Basic)**
- Students use materials of their choice to demonstrate how acceleration is affected when the net force is doubled on an object while the mass is kept constant. **(Proficient)**
- Students measure the speeds of various sizes of ball bearings on inclined planes with different slopes. They graph the collected data and present their findings to the class. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 10

Basic

10-1 When touring a restored wooden battleship, you notice that the cannons are tied to the ship with heavy rope. In addition to preventing them from moving around in rough seas, give one reason why these ropes might have been used.

(Panel)

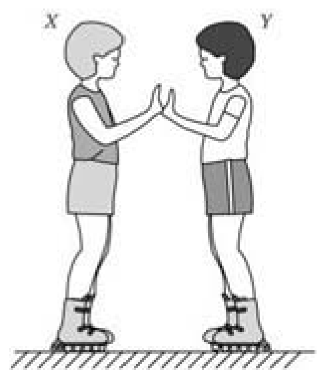
Proficient

10-2 To keep a heavy box sliding across a carpeted floor at constant speed, a person must continually exert a force on the box. This force is used primarily to overcome which of the following forces?

- (A) air resistance
- (B) the weight of the box
- (C) the frictional force exerted by the floor on the box
- (D) the gravitational force exerted by the Earth on the box

(NAEP)

10-3 Two boys wearing in-line skates are standing on a smooth surface with the palms of their hands touching and their arms bent as shown to the right. If Boy X pushes by straightening his arms out while Boy Y holds his arms in the original position, what is the motion of the two boys?

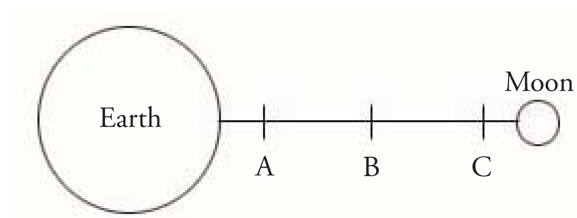


- (A) Boy X does not move and Boy Y moves backward.
- (B) Boy Y does not move and Boy X moves backward.
- (C) Boy X and Boy Y both move backward.
- (D) The motion depends on how hard Boy X pushes.

(NAEP)

Advanced

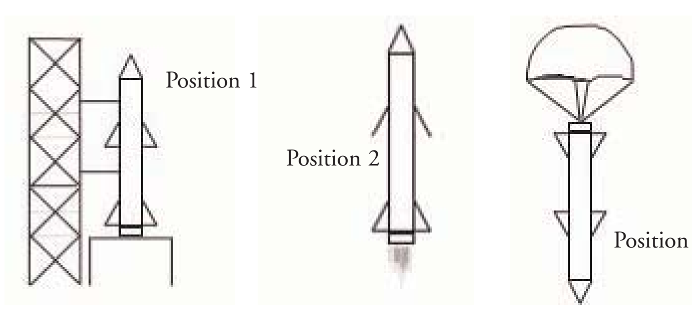
10-4 A space station is to be located between the Earth and the Moon at the place where the Earth's gravitational pull is equal to the Moon's gravitational pull. On the diagram below, circle the letter indicating the approximate location of the space station. Explain your answer.



(NAEP)

10-5 The drawings show a rocket being launched from Earth and then returning.
In which of the three positions does gravity act on the rocket?

- (A) 3 only
- (B) 1 and 2 only
- (C) 2 and 3 only
- (D) 1, 2 and 3



(TIMSS)

Sample Investigation* for Content Indicator 10: Describe the relationship between forces and motion with regard to Newton's laws.

Slip Sledding Away

Scenario Your class has been challenged by another class to a sledding contest on a hill covered with newly fallen snow. The rules are

- Each class builds one sled of any design and materials.
- Each class can put any number of students in or on the sled.
- At a spot just before the top of the hill (still on a slope), the sleds are held by ropes, side by side. Students get in or on the sleds and the ropes are removed.
- The sled that travels the farthest wins.

Students conduct research to learn more about the variables involved in sled design. Then they discuss the following questions to help them critique and frame the design of their investigations.

- Should only one student be in or on the sled?
- What materials should be used to make the sled (wood, metal, wood with a special surface for the bottom, etc.)?
- Should the area of the bottom of the sled be large or small in relation to the size of the sled?
- Should the sled be closed (so that students are inside the sled) or open (so that students are on top of the sled)?
- Should the student(s) be in or on the sled (seated, lying down or standing up)?

1. Design a scientific investigation.

- Students review the discussion questions and predict which variable (number of riders, materials, bottom surface area, closed or open, and position of rider) they think has the greatest impact on designing a sled that will travel the farthest and why. They critique the experimental design provided to them that addresses the variable they have chosen. Their critiques include identifying the variables, determining whether the variables are controlled reasonably well and whether the design of the investigation addresses their research question. They also describe how to improve the design and formulate other possible research questions. **(Basic)**
- Students review discussion questions and predict which variable they think has the greatest impact on designing a sled that will travel the farthest and why. Then students design an investigation to answer the discussion question they have chosen. **(Proficient)**
- After conducting research on sled design, some students say that making an aerodynamic sled will increase the distance traveled, but that the difference would be so small it wouldn't be worth the effort. Other students say an aerodynamic sled would only make a difference if it is large and holds several students. Still others say that an aerodynamic sled would make a significant difference in each situation. Students design investigations to test the hypotheses and predictions. **(Advanced)**

2. Conduct a scientific investigation.

- Students follow a set of steps in the investigation given to them and record their observations of the conditions and the results of each trial. **(Basic)**
- After designing their own investigation, students record their measurements (data) for multiple trials and compute means. They include the conditions of each trial by noting the characteristics of the materials used for the bottom surface, the changes in the area of the bottom surface, and other variables, such as surface area and mass as they correlate the variables to the distances traveled. Students monitor variables to ensure consistency across trials. Students design a system to evaluate materials. **(Proficient)**

* A sample rubric for evaluating student scientific investigations is on page 13.

- In addition to recording data, students include the conditions of each trial and the results, and compute the measures of central tendency (mean, median and mode). They also critique the characteristics of the aerodynamic design and record the distances traveled to the appropriate degrees of precision. Students monitor variables to ensure consistency across trials and measure other variables, such as mass. Students design a system to evaluate the different aerodynamic designs. **(Advanced)**

3. Analyze findings of a scientific investigation.

Students review the data to formulate their conclusions and answer the following questions:

- Which sled travels the farthest? Describe it in detail. **(Basic)**
- How do these findings compare with your original predications? **(Basic)**
- Do your results support your predictions? If not, give some reasons why. Include details regarding the five variables (number of students, materials, area of bottom, open or closed and position of student) identified in the discussion questions. **(Proficient)**
- After reviewing the data, how would you redesign your sled to make it more aerodynamic? **(Advanced)**
- What other factors could have affected the performance of your sled? **(Advanced)**

4. Communicate and defend findings.

- Based on their analyses of their data, students write a brief summary or give a brief oral report. Students create a simple graph to show the distances traveled by all of the sleds. Discussion should include students' understanding of the impact of the variables on the distances traveled by the sleds. **(Basic)**
- Students write a summary of their investigation, a step-by-step description of the design of their investigation, and an explanation of how their investigation provides information to answer the original questions. They graph their data to present and defend their conclusions to the class. **(Proficient)**
- Students write a research report. Based upon their report and investigation, they create a multi-media presentation to support their conclusions and their defense of them to the class. They draw conclusions about whether an aerodynamic design, its size and number of riders significantly increased the distance the sled traveled. **(Advanced)**

5. Evaluate other scientific investigations and apply results.

Students review the data to formulate their conclusions and answer the following questions:

- How do their investigations and conclusions differ from yours? Explain. **(Basic)**
- What changes would you make in your sled design? **(Basic)**
- How do you think an actual sled race would differ from your investigation? **(Basic)**
- Using your results, do you think it makes a difference to skiers, snowboarders and skateboarders whether their skis and boards are long or short, or wide or narrow? Explain. **(Proficient)**
- Using your results, rank the sled designs based on distances traveled. **(Proficient)**
- Historically what changes have been made in the designs of the bobsled? Include in your study the history of Olympic bobsled events and write a report of your findings to present to the class. **(Proficient)**
- Review and analyze the data from all teams to identify other factors you think may influence the distance a sled travels. **(Advanced)**
- What if, in the actual race, there were a wind blowing directly toward you? How important would aerodynamics be then? Design a method of predicting the effects of headwinds at different speeds. **(Advanced)**

11 *Life Science*
Describe the parts and systems of living things and relate them to need, function and classification.

Middle grades students need to know about the basic structures and functions of cells; about how cells are organized into more complex structures, such as tissues and organs; and how different organ systems work together to carry out specialized complex functions. In the middle grades students need to understand how systems work together to maintain and protect stability within the body and understand what happens when a structure fails and homeostasis is not maintained.

All living things are made of cells — the basic units of life. Students can use their knowledge of specialization of cells, structures and systems to classify living things into groups using similarities in structure and function. The physical features and biochemical analyses of organisms provide information about how to classify them and about their evolutionary origins. Students can explain how the most closely related organisms are grouped into a species level and how less closely related organisms are classified in the same kingdom.

By the end of the middle grades students' grasp of cells, tissues, organs and systems provide a necessary foundation for high school biology, and anatomy and physiology courses. Teachers can build on students' knowledge of the parts of the body, internal organs and systems by using instructional aids such as microscopes, photographs, diagrams, thermometers, blood pressure gauges and three-dimensional models that help students understand the concepts involved in structure and function in living things. This information is crucial for success in college-preparatory biology, genetics, and anatomy and physiology.

Launch

As you read the daily newspaper, an article about the birth of a baby catches your attention. The doctors relay the sad news that the right hemisphere of the baby's brain has not developed. Because of the complexity of the nervous system and compensation when one part fails, the doctors are fairly optimistic that the baby will develop and live a somewhat normal life. You are confused. How can this be? Isn't the brain necessary?

THINK!!!

1. What functions are controlled by each hemisphere of the brain? **(Prior knowledge)**
2. Can other systems or organs compensate for the loss? **(Research)**
3. What can the parents do to help the baby overcome this handicap? **(Prior knowledge and Research)**
4. Research similar examples of compensation. **(Research)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
■ Describe the levels of organization of living things.	■ Compare and contrast the levels of organization of living things.	■ Analyze the relationships between the levels of organization of living things.
■ Identify the characteristics of cells and tissues.	■ Understand the structure and function of cells and tissues.	■ Correlate defects in cells and tissues to specific conditions.

Learning Activities and Applications

- Students use compound microscopes and prepared slides of plant and animal cells and tissues to identify components. They draw the various cells and tissues and discuss the structures as they relate to various functions. Students use their drawings for a classroom display. **(Basic)**
- Students make wet-mount slides of various plants such as *Elodea*. Cheek cells can be prepared (with careful teacher supervision) or purchased as an example of animal cells. Students use a compound microscope to observe the slides and discuss the similarities and differences. A Venn diagram can be used to display similarities and differences. Students present results to the class. **(Proficient)**
- Students make wet-mount slides of plant and animal cells and discuss the correlation between structure and function. Students use various concentrations of saline and other solutions to determine the effect of these on cells. They present findings to the class. **(Advanced)**

- Given a list of 15 items found in the classroom, students determine which are living (or once lived) and which are nonliving. Explain the reasoning for each answer. **(Basic)**
- Using the following items: a piece of moldy bread, a jar of green algae, a flowering plant, a hamster in a cage, a Petri dish (completely secured), a plastic bowl and a paper clip, students observe each item carefully and develop a procedure to determine which items are living and which are nonliving and explain how they would test each one to be sure. **(Proficient)**
- Students construct a three-dimensional model of an improved version of an organ, describe required parts (sensors, transmitters, and parts that break down, put together or transport materials), and compare to actual organs and existing artificial ones. Prepare a sales pitch explaining the improved benefits of the model and convince the class of the benefits. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 11

Basic

11-1 The smallest organisms have how many cells?

(A) 0 (B) 1 (C) 2 (D) 32 (E) 64

(Panel)

Proficient

11-2 In the human body the digestion of proteins takes place primarily in which two organs?

(A) mouth and stomach
(B) stomach and small intestine
(C) liver and gall bladder
(D) pancreas and large intestine

(NAEP)

11-3 Humans interpret seeing, hearing, tasting, and smelling in the:

(A) brain (B) spinal cord (C) receptors (D) skin

(TIMSS)

11-4 Which of these is NOT a function of blood?

(A) digesting food
(B) protecting against disease
(C) carrying waste materials away from the cells
(D) carrying oxygen to different parts of the body

(TIMSS)

Advanced

11-5 Describe how the nutrients from digested bread move from the digestive organs to muscles and other tissues where they are needed.

(NAEP)

12 *Life Science*
Recognize that the traits of an individual organism are a combination of inherited traits and acquired traits.

During the middle grades students build on their understanding of the importance of each organism as unique with distinguishing characteristics that reproduces its own kind. Middle grades students can explain that each organism within a species has a unique combination of traits inherited from parents and acquired traits developed through environmental influences. By the end of the middle grades, students can explain that genetics involves numerous laws and patterns of heredity. They build on knowledge that genes are the fundamental units of heredity and have two or more forms, may produce dominant or recessive traits and are passed from parent to offspring. These traits can be followed by using family histories and pedigree charts.

Knowledge of inherited and acquired traits is essential to students' understanding of the foundations of genetics and inheritance. Teachers can help students understand that the location and actions of genes and chromosomes within the nuclei of cells are the basis for the more complex laws of segregation, dominance and independent assortment. This prepares students for advanced studies in genetics, and the anatomy and physiology of plants and animals. Pedigree charts, Punnett squares, photographs and probability exercises aid students in understanding genetics and prepare them for high school life science courses.

Launch

In order to increase the number of koala bears, zoologists are using artificial insemination and raising the babies in specially protected habitats. As these babies grow into adults, many changes have been observed in the way they interact and socialize with other koalas.

THINK!!!

1. What changes would you expect to see in their behaviors? **(Brainstorming)**
2. How can zoologists protect the koala's natural behaviors? **(Brainstorming and Research)**
3. Are there other species affected in similar ways? **(Research)**
4. What advice would you give to the caretakers of the koalas? **(Research and Creativity)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
■ Describe inherited and acquired characteristics.	■ Distinguish between inherited and acquired characteristics.	■ Illustrate the pedigree of a specific family.
■ Diagram monohybrid testcrosses and probabilities.	■ Diagram dihybrid testcrosses and probabilities.	■ Diagram dihybrid testcross; include blended factors and probabilities.
■ Understand the use of genetic engineering.	■ Relate changes resulting from genetic engineering to real life.	■ Predict the impact of genetic engineering on future products.

Learning Activities and Applications

- Students research the characteristics that animals (like polar bears) inherit (survival of the fittest) that help them survive in extreme conditions. They create and present shoebox dioramas of the results for a class display. **(Basic)**
- Given a pedigree chart of a family for several generations, students determine the probability of dominant and recessive traits being transmitted and expressed. They share their results with the class. **(Proficient)**
- Students research to compare and contrast the features of plants and animals that have been selectively bred with those of their parents. **(Advanced)**

- Given two pennies and a list of simple dominant and recessive characteristics, students toss both coins at the same time to determine which traits the offspring inherits (homozygous dominant, homozygous recessive or heterozygous). Students draw the offspring with its characteristics, and present and explain the drawing to the class. **(Basic)**
- Students develop a list of dominant, recessive and blended characteristics for an organism. They predict the outcomes if two coins are tossed to determine the phenotype for each characteristic. After completing the tosses, they compare the outcomes to their predictions and explain their findings. **(Proficient)**
- Students research a specific genetic disease. They research evidence of, data and information about its occurrence. They design a questionnaire for potential parents to determine the probability of their child inheriting that condition. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 12

Basic

12-1 Which of the following ways would you NOT expect to see a child resemble a parent:

(A) eye color

(B) hair color

(C) height

(D) scars

(Panel)

Proficient

12-2 Hair color in humans is an inherited trait. How is it possible for two people who had brown hair from birth to produce a child with blond hair?

(NAEP)

Advanced

12-3 Elise has blue eyes. Her father has brown eyes. Given this information, can you determine whether her mother has blue or brown eyes? Why or why not?

(Panel)

13 *Life Science*

Identify adaptation and natural selection as processes that have resulted in the diversity of plant and animal life.

During the middle grades, students build on their knowledge that all the genes for all the inherited traits in an adult population make up the gene pool, and the inheritance of specific genes enable individual organisms to be better suited to the environment. Students can discuss that populations are members of the same species living in a certain area and that individuals within a population generally have a great variety of genes, as well as adapted behaviors. Those best fitted to live in their surroundings seem to survive and reproduce. This process is known as the theory of natural selection.

Students leaving the middle grades understand about the impact of natural selection and the resulting variations in offspring. They understand that individual organisms develop adaptations to their environments that they do not pass on to their offspring. Students can explain that environmental changes favor the organisms with characteristics necessary to survive.

Investigations and discussions about differences in inherited and acquired traits provide students with the knowledge to succeed in biology, genetics and anatomy and physiology classes in high school. By reviewing examples of survival in different organisms such as peppered moths and light- and dark-colored rabbits, teachers can help students develop conclusions about population genetics, speciation and genetic equilibrium. Students can demonstrate that environmental changes and genetic variation may require long periods of time to occur.

Launch

Young bears often look very similar. During a recent release of young bears into the wild, a new park ranger accidentally allowed a young polar bear to escape into the state park where grizzly bears are commonly found. What will happen?

THINK!!!

1. What advantages or disadvantages does the polar bear have for surviving in the different environment? **(Brainstorming)**
2. How would its day be different from a day in its normal habitat? **(Predicting)**
3. What are some examples of animals adapting and surviving in new environments? **(Research)**
4. Use the example of the polar bear and explain how adaptation and natural selection can be helpful and/or harmful. **(Research)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
■ Describe and demonstrate populations and species.	■ Model the impact of gene mutations on a population and species.	■ Demonstrate and explain how biotechnology can improve a population and species.
■ Model how an organism becomes extinct.	■ Assess and demonstrate the impact on ecosystems when an organism becomes extinct.	■ Create an environment that eliminates the danger of extinction for a specific organism.

Learning Activities and Applications

- Each student is given a card with the name of a specific organism. Students create food chains and then food webs (or flow charts) by using string to connect each card to another card (predator or prey). They explain the connections. **(Basic)**
- Given a specific number of organisms and designated amounts of food, water and shelter in an ecosystem, students role play the impact as these biotic and abiotic factors change. They record and graph the data as the populations change. They present their graphs to the class. **(Proficient)**
- Each student group researches a specific biome and determines the organisms common to that environment. Each group constructs an ecological pyramid showing correct placement for each organism and describes how the amount of energy changes from one level to another. Groups present their findings to the class. **(Advanced)**

- Given three test tubes with samples of the algae *Chlorella* in three solutions (phosphate, nitrate and distilled water), each student group checks the growth of the algae and discusses any changes in the test tubes. Groups chart and present their findings to the class. **(Basic)**
- Given test tubes and algae (*Chlorella*) samples, each student group designs an investigation to determine if detergents change the reproductive rates of the algae. Groups present their findings to the class. **(Proficient)**
- Using algae or water plants, each student group designs and conducts an investigation about the growth of the algae when commonly used laundry detergents are found in the water. They assess the value of their findings when they present to the class. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 13

Basic

13-1 Scientists can use fossils in rocks to

- (A) study the evolution of animals.
- (B) learn about past environments.
- (C) match up rock layers at different places.
- (D) all of the above.

(Panel)

13-2 A diagram shows layers of sediments in a body of water. In which layer would the oldest fossils be found?

water
layer A
layer B
layer C
layer D

- (A) layer A
- (B) layer B
- (C) layer C
- (D) layer D

(Panel)

Proficient

13-3 Which of the following is most consistent with the modern theory of evolution?

- (A) Parents pass their physical traits to their offspring; those offspring with traits that help them survive in the environment are able to reproduce.
- (B) Parents change their physical traits in order to survive in the environment, and then those parental traits are passed to their offspring.
- (C) Life on this planet came from another planet far out in space.
- (D) Living organisms have not changed for hundreds of millions of years.

(NAEP)

13-4 Insecticides are used to control insect populations so that they do not destroy crops. Over time, some insecticides become less effective at killing insects, and new insecticides must be developed. What is the most likely reason insecticides become less effective over time?

- (A) Surviving insects have learned to include insecticides as a food source.
- (B) Surviving insects pass their resistance to insecticides to their offspring.
- (C) Insecticides build up in the soil.
- (D) Insecticides are concentrated at the bottom of the food chain.

(TIMSS)

Advanced

13-5 Using the information in the table determine whether the trait and function of each organism listed is inherited or acquired.

Organisms and Adaptations

Organism	Habitat	Trait	Function
owl	woodlands	talons for hunting	tears flesh
arctic hare	arctic	white fur in winter	provides camouflage
hummingbird	woodlands	long beak	reaching into feeder for food
giraffe	grasslands	long neck	reaching leaves on trees

(Panel)

14 *Life Science*
Describe relationships in ecosystems among organisms and between organisms and their environments.

During the middle grades students experience activities showing that changes on Earth are the result of the interactions among living things and between living things and their environments. Students can explain that energy flows through the ecosystem and creates food chains, food webs and other cycles. Students can discuss and summarize how habitat destruction; poor agricultural practices; and pollution of air, water and land change the interactions between living things and the environment and affect the energy flow through the entire biosphere.

Upon leaving the middle grades, students can identify and explain specific types of helpful relationships such as mutualism and commensalism. Students understand harmful interactions such as parasitism, amensalism and predation and the impact of natural disasters on an environment and the organisms living there. Students' experiences with food chains, food webs, producers, consumers and decomposers prepare them for classes in biology, botany and zoology, and in career/technical classes dealing with deforestation, conservation and ecology. Teachers can guide students to develop knowledge and skills in sampling techniques, identification of various plants and animals, and to analyze the impact of overpopulation, urban sprawl and fossil fuels on the environment.

Launch

As your older brother prepares to leave for college, he asks you to take care of the aquarium in his room. You decide it will be easier if you put his fish into your tank so you will have only one tank to care for. All is well for a while, but within a month, all of the fish and plants have disappeared or died, except for one large fish. How do you explain this to your brother?

THINK!!!

1. What do you think happened? **(Brainstorming)**
2. Account for the demise of the fish compared to the plants. **(Prediction)**
3. What do you need to know before combining fish and plants? **(Research)**
4. How could you prevent this catastrophe in the future? **(Investigate)**

Benchmark Proficiency Progression

Basic	Proficient	Advanced
■ Describe biotic and abiotic factors in the local environment.	■ Observe and compare biotic and abiotic factors in different habitats.	■ Conclude, support and model the impact of changes in biotic and abiotic factors.
■ Demonstrate the role of producers, consumers and decomposers in an ecosystem.	■ Demonstrate the impact of producers, consumers and decomposers on a food web.	■ Analyze and model the results of a change in specific producers, consumers or decomposers in a food web.
■ Demonstrate how different pollutants develop.	■ Model the impact of various pollutants.	■ Simulate changes on Earth that result from pollutants.

Learning Activities and Applications

- Given 10 items of household trash (that can be safely handled) each student group sequences the items in order of rate of decomposition in a landfill. They conduct research to find the expected rates of decomposition, compare the rates and present the results to the class. **(Basic)**
- Given 10 items of household trash (that can be safely handled) each student group investigates methods of increasing the rate of decomposition (or an alternative use) of the items. Each group creates a graphic to illustrate the process to the class. **(Proficient)**
- In a permanent research station on Mars, continual recycling of all materials will be necessary. Each student group designs a spaceship that recycles as many products as possible. Groups present sketches and their findings to the class. **(Advanced)**

- Each student researches and explains the impact of one type of pollutant on the environment. The student presents and defends his/her findings to the class. **(Basic)**
- Each student group designs an investigation to test the impact of pollutants on the environment. Examples can include water quality in local bodies of water, runoff from construction sites or losses of habitat, etc. Groups present their investigative designs to the class. **(Proficient)**
- Each student group designs and develops a model of an alternative process or product to replace one currently polluting the environment. The method or product will reduce the negative impact on the environment. Groups present their designs and models, and convince the class that the designs work. **(Advanced)**

Proficiency Level Illustrations for Content Indicator 14

14-1 Which group of organisms would all be found living in a tropical rain forest?

- (A) lizards, insects, cacti, kangaroos
- (B) vines, palm trees, tree frogs, monkeys
- (C) evergreens, moose, weasels, mink
- (D) lichens, mosses, caribou, polar bears

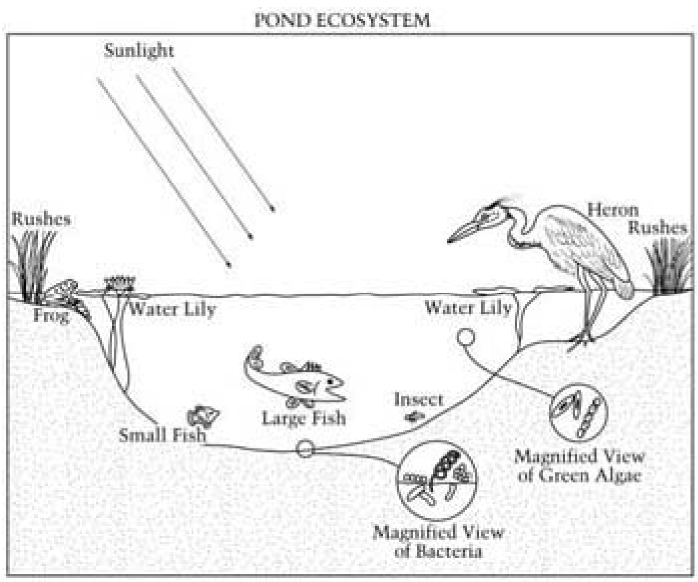
(NAEP)

14-2 A certain organism has many cells, each containing a nucleus. If the organism makes its own food, it would be classified as:

(A) a bacterium (B) fungus (C) a plant (D) an animal

(NAEP)

The picture below shows a pond ecosystem. Use this picture and what you know about the things in it to answer questions **14-3** and **14-4**.



14-3 Which of the following living things in the pond system uses the energy from sunlight to make its own food?

(A) insect (B) frog (C) water lily (D) small fish

(NAEP)

14-4 In the pond, small fish eat algae. What two predators might eat the small fish in the pond system?

(NAEP)

Basic

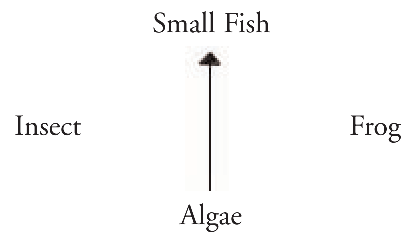
Refer to the pond ecosystem on page 61 to answer questions **14-5 — 14-11**.

Proficient

14-5 Each of the animals in the pond needs food. What are the two things that animals get from their food that keep them alive?

(NAEP)

14-6 You will now finish a diagram of a food web in the pond. The food web shows what eats what in the pond system. Draw arrows in the diagram below from each living thing to the things that eat it. (The first arrow is drawn for you.)



(NAEP)

14-7 Which animal is the top carnivore in the pond system? Explain why you chose this answer.

(NAEP)

14-8 If air pollution causes the rain that falls on a pond to become much more acidic, after two years how will this acidity affect the living things in this pond?

- (A) There will be more plants and animals because the acid is a source of food.
- (B) There will be fewer plants and animals because the acid will dissolve many of them.
- (C) There will be fewer plants and animals because many of them cannot survive in water with high acidity.
- (D) There will be more plants and animals because the acid will kill most of the disease-causing microorganisms.

(NAEP)

Advanced

14-9 Suppose that one spring a new type of large fish was put into the pond. So many were put in that there were twice as many fish as before. By the end the summer, what would happen to the large fish that were already in the pond? Explain why you think these new large fish would have this effect.

(NAEP)

14-10 Suppose that a farmer near the pond sprayed crops with a pesticide to kill insects and that some of the spray washed into the pond. (This pesticide breaks down very slowly.) If several months later a biologist tests all the organisms in the pond system for the pesticide, which organism would most likely have the greatest concentration of the pesticides? Explain your answer.

(NAEP)

14-11 A potted plant can survive in a sealed glass container for a long time, but you would not put a mouse in such a sealed container for even a short period of time because it would quickly die. Explain why the plant can survive and the mouse cannot.

(NAEP)

Sample Investigation* for Content Indicator 14: Describe relationships among organisms and between organisms and their environments.

Your Neighborhood Food Web

Scenario After your teacher announces that your class will begin a unit on food chains and food webs; one of your classmates makes the statement that food chains exist only in the jungle.

- Do you agree with your classmate?
- Do you think there are food chains everywhere, even in your neighborhood?

Drawing upon their prior knowledge, students brainstorm and identify the organisms that they think might be found in their neighborhood.

1. Design a scientific investigation.

- Students critique the following investigation:

  Each student has a notebook and drawings or photographs with descriptions of several organisms found in your neighborhood. For an hour students walk around in different sections of the area and record the number of times they observe the organisms. After repeating their observations a total of five times during a week, students calculate the mean for each species and report their findings to the class.

  Students answer the following in their critique: Is this a good method to estimate populations? Explain why or why not? **(Basic)**
- Students use the list of organisms they brainstormed and design a procedure for estimating the populations of organisms in a given area of their neighborhood. Their designs include at least five organisms, observations in different locations and at different times of day, and a method of estimating populations based on observed samples. **(Proficient)**
- Students design a procedure for cataloging all the living things in the area, estimating the populations of at least five species, and identifying at least five producer/consumer or predator/prey relationships. Designs should include methods of direct observations, such as counting actual numbers of organisms, and indirect observations, such as animal tracks, skeletons, feathers, shells, discarded food, and so on, and a method of estimating populations based on observed samples. **(Advanced)**

2. Conduct a scientific investigation.

- Students are given a procedure for identifying the organisms in the area and for estimating the population of at least one organism. They use hand lenses and binoculars to record the number, habitat and location of each organism. Students understand the importance of respecting the environment of organisms and of following safety rules regarding living things, especially those that are unknown or dangerous. Students document any bodies of water and land features. **(Basic)**
- Students develop a procedure of their own to identify the organisms in the area. They estimate land areas and bodies of water and use their recorded data to estimate the populations of the organisms they observed. Students brainstorm possible relationships between organisms. **(Proficient)**
- Students write a procedure of their own to identify the organisms in the area. Students recognize and describe instances when conditions or the method of observation make the sample less useful. Students report population estimates using appropriate levels of precision. Students conduct background research regarding the organisms observed. Students choose one observed organism and predict its relationship in the neighborhood food chain. Then they design a way to document the organism's actual relationship, such as no relationship, predator/prey or producer/consumer. **(Advanced)**

* A sample rubric for evaluating student scientific investigations is on page 13.

3. Analyze findings of a scientific investigation.

- Students review their data to formulate conclusions and answer the following questions:
  - What organisms did you identify?
  - How do your findings compare with your brainstorming list?
  - Do you think changes in the seasons will affect the populations of the organisms you observed?
- Students sketch a simple food chain based on their observations. **(Basic)**
  - What are some reasons why your estimates might be too high or too low?
  - Which predator/prey and producer/consumer relationships were you able to identify? How did you identify these?
- Based on their observations, students create a food chain and simple food web. **(Proficient)**
  - Did your design give you sufficient data to predict the populations of organisms in your neighborhood and verify the relationships between organisms? Explain why or why not.
  - How do you think the populations in your area and the relationships among them have changed over the last 50, 100, 500, and 1 million years?
- Students review the data and create a food web to show their observations of the relationships between organisms in the area. **(Advanced)**

4. Communicate and defend findings.

- Students write a brief summary and give a brief oral report on possible food chains. Using their data students create charts and graphs showing numbers of observed organisms at different sites. They calculate the measures of central tendency (mean, median and mode) for each population. **(Basic)**
- Students write a summary of their investigation design, including the purpose and expectations, the method for identifying organisms and estimating populations, and the findings. Students create a map showing where observations were made and what was found. **(Proficient)**
- Students write a summary of their investigation, including the purpose and expectations, the methods for identifying species, and the findings. Using their data students create a map showing where observations were made and what was found and they make a food web illustrating the predator/prey and producer/consumer relationships identified. Students' graphs show the comparison of population sizes and illustrate likely changes in population from different causes over time for a classroom display. **(Advanced)**

5. Evaluate other scientific investigations and apply results.

Students review their classmates' reports and provide their answer to the questions in the scenario. They also answer the following questions by describing investigations to support their answers.

- How do their methods and findings differ from yours? **(Basic)**
- Based on their methods, do you think their population estimates are accurate? Explain. **(Basic)**
- Will the populations change over the next 10 years? **(Basic)**

In addition to the questions at the Basic level, students answer the following:

- Is this design the best way to determine the populations and relationships in a food web? If not, explain. **(Proficient)**
- What procedure could you use to verify your conclusions? **(Proficient)**

In addition to the questions at the Proficient level, students answer the following:

- Evaluate the overall procedure for estimating populations and account for any possible errors. Redesign and repeat the procedure to gather more information about the food chain and food web. Predict how each population might change over a calendar year and over the next 10 years. **(Advanced)**

Answers to Proficiency Level Illustrations

1-1 C

1-2 D

1-3 B

2-1 Some areas of dry land were once in the ocean. The mountain forming process has elevated areas which were in the ocean and now dry land.

2-2 E

2-3 Use a tumbling device such as a rock polisher filled with water, rocks and sand. As the tumbling occurs over time the rocks would grind against each other and change in shape and size.

2-4 C

2-5 (dry land that once was in the ocean) Evidence: any fossils of sea life — mollusks, fish, etc.; wave rippling marks on rocks; salt deposits
(same land mass) Evidence: similar fossils (plants and animals), similar rock types/formations, shapes of the two continents

3-1 Mercury would have the smallest elliptical orbit, Venus the next, Mars the largest orbit around the Sun. None of the orbits will intersect and each has an arrow indicating a clockwise direction.

3-2 The planets orbit around a center, the Sun. The further the orbits are from center (the Sun), greater the distances (lengths) of the orbits. The Sun is larger than any of the planets which have different sizes.

3-3 The Sun would be MUCH larger, too large to represent to scale.

3-4 A

3-5 One's shadow would be longer in winter (in the northern hemisphere) because the tilt of Earth away from the sun causes the sun's rays to strike Earth at a greater angle (more indirect light).

3-6 A

4-1 B

4-2 C

4-3 A

4-4 The colder, denser air will move under the warmer, less dense air. As the warm air rises, it cools and the moisture condenses forming rain.

5-1 run-off to a stream and then to a lake (or to the ocean); evaporation into the air (vapor); condensation (cooling) back to water or rain

5-2 A

5-3 Evaporation → Wind, air currents → Condensation

```
 ^  ^  ^          (cooling)          /   /
/  /  /                              v   v
^^^^^^
 Ocean                               Rain
```

5-4 Areas on the leeward sides of mountains can be dry because the moisture is lost as air rises on the opposite sides (cooling and condensing). Prevailing winds can cause some areas to be dry by not allowing moist air to enter the area (Sahara).

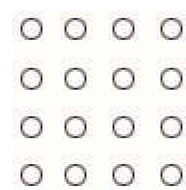
6-1 C

6-2 D

6-3 A

6-4 Water is denser than alcohol, so the same volume would have more mass.

Water



Alcohol

7-1 A boiling (physical); B rusting (chemical)

7-2 B

7-3 2Fe (II) + O_2 → 2Fe(II)O

The reactants, oxygen and iron would not come into contact with each other because of the paint barrier.

8-1 B

8-2 C

8-3 Fluorescent, less energy is lost as heat.

8-4 B

8-5 D

8-6 D

9-1 The clapper hits the metal bell causing it to vibrate. The vibrating metal of the bell creates a disturbance or vibration in the air next to the metal. This energy is transferred from air molecule to air molecule establishing a wave. This wave comes in contact with the ear drum and establishes vibrations of the ear drum.

9-2 D

9-3 A

9-4 1. Fluorescent bulbs do not create significant amounts of UV radiation, the radiation responsible for sunburn. 2. The person in the room is shielded from the sun, which does produce significant amounts of UV radiation. UV will not penetrate the roof of the building.

9-5 The sound is bounced or reflected off the walls and empty seats, the first time. The audience absorbs the energy of the sound waves, the second time.

9-6 a. No, the light beam disperses or expands as it travels away from the source. There is not more light reflecting from the ceiling, but rather light dispersed over a greater area.

10-1 The ropes help minimize the effect of recoil. As the cannon fires, the explosion creates a force in all directions, including backward. The ropes help reduce the backward movement of the cannon and also provide a means of pulling the cannon back into place.

10-2 C

10-3 C

10-4 C; Gravitational pull depends on mass and distance so the station must be closer to the Moon because the Moon's mass is less than Earth's.

10-5 D

11-1 B

11-2 B

11-3 A

11-4 A

11-5 The nutrients are absorbed by blood in the small intestine and carried to the muscle tissue. Here the nutrients enter the cell through the cell membrane via active transport.

12-1 D

12-2 Blond could be a recessive trait, carried by both parents.

12-3 No. Since blue eyes are recessive, Elise's father must be heterozygous for eye color. Her mother could be heterozygous brown-eyed or she could be homozygous blue-eyed.

13-1 D

13-2 D

13-3 A

13-4 B

13-5 owl — inherited and inherited; artic hare — inherited and inherited; hummingbird — inherited and acquired; giraffe — inherited and inherited

14-1 B

14-2 C

14-3 C

14-4 heron or large fish

14-5 energy and nutrients such as proteins, carbohydrates, vitamins, etc.

14-6 arrow from insect to small fish; arrow from algae to insect

14-7 heron; no natural enemies in this web

14-8 C

14-9 A large fish population would decrease due to increased competition.

14-10 The large fish and/or heron are at the top of the food web so the pesticide would be concentrated in them.

14-11 The plant produces oxygen during photosynthesis. This oxygen can be used during the plant's respiration. Mice do not produce oxygen; they only use it during respiration.

HSTW Goals

- Raise the mathematics, science, communication, problem-solving and technical achievement of more students to the national average and above.
- Blend the essential content of traditional college-preparatory studies — mathematics, science and language arts — with quality career/technical studies by creating conditions that support school leaders, teachers and counselors in carrying out key practices.
- Advance state and local policies and leadership initiatives necessary to sustain a continuous school-improvement effort for both academic and career/technical students.

HSTW Key Practices

High expectations — setting higher expectations and getting more students to meet them

Career/technical studies — increasing access to intellectually challenging career/technical studies, with a major emphasis on using high-level mathematics, science, language arts and problem-solving skills in the modern workplace and in preparation for continued learning

Academic studies — increasing access to academic studies that teach the essential concepts from the college-preparatory curriculum by encouraging students to use academic content and skills to address real-world projects and problems

Program of study — having students complete a challenging program of study with an upgraded academic core and a major

Work-based learning — giving students and their parents the choice of a system that integrates school-based and work-based learning. The system should span high school and postsecondary studies and should be planned by educators, employers and employees

Teachers working together — having a organization, structure and schedule giving academic and career/technical teachers the time to plan and deliver integrated instruction aimed at teaching high-level academic and technical content.

Students actively engaged — getting every student involved in rigorous and challenging learning

Guidance — involving all students and their parents in a guidance and advising system that ensures the completion of an accelerated program of study with an in-depth academic or career/technical major

Extra help — providing a structured system of extra help to enable students who may lack adequate preparation to complete an accelerated program of study that includes high-level academic and technical content

Keeping score — using student assessment and program evaluation data to improve continuously the school climate, organization, management, curricula and instruction to advance student learning and to recognize students who meet both curriculum and performance goals

MMGW Goals

- Increase the percentages of eighth-graders who perform at the Basic and Proficient levels in academic subjects.
- Provide educational experiences that increase students' knowledge and skills in reading, mathematics, language arts, science and social studies.
- Provide students with opportunities to apply their skills in the fine arts and to explore careers and new technology.

MMGW Key Practices

An academic core — All students in the middle grades need an academic core curriculum that accelerates their learning so they succeed in college-preparatory English, mathematics and science.

All students matter — Each middle grades student needs an adult who takes interest in his or her successful learning, goal-setting, educational planning and personal growth.

High expectations and extra time and help — Middle grades students need enough time and help to meet more rigorous, consistent standards in a curriculum that accelerates achievement for all students.

Classroom practices that engage students — Young adolescents need varied learning activities linked to challenging academic content and opportunities to use new skills and concepts in real-world applications.

Use of data — States, districts and schools continuously must use data on student, school and teacher performance to review and revise middle grades school and classroom practices as needed.

Teachers working together — All middle grades teachers need time to plan together, to develop and coordinate learning activities, and to share student work that meets proficiency standards.

Support from parents — Parents must understand clearly and must support the higher-standards for performance in the middle grades.

Qualified teachers — Middle grades teachers must know academic content and how to teach young adolescents.

Use of technology for learning — Middle grades students and teachers must have opportunities to explore and use technology to improve knowledge and skills in English/language arts, reading, mathematics, science and social studies.

Strong leadership — Middle grades schools need strong, effective principals who encourage teachers and participate with them in planning and implementing research-based improvements.

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Challenge to Lead Goals for Education

1. All children are ready for the first grade.
2. Achievement in the early grades for all groups of students exceeds national averages and performance gaps are closed.
3. Achievement in the middle grades for all groups of students exceeds national averages and performance gaps are closed.
4. All young adults have a high school diploma — or, if not, pass the GED tests.
5. All recent high school graduates have solid academic preparation and are ready for postsecondary education and a career.
6. Adults who are not high school graduates participate in literacy and job-skills training and further education.
7. The percentage of adults who earn postsecondary degrees or technical certificates exceeds national averages.
8. Every school has higher student performance and meets state academic standards for all students each year.
9. Every school has leadership that results in improved student performance — and leadership begins with an effective school principal.
10. Every student is taught by qualified teachers.
11. The quality of colleges and universities is regularly assessed and funding is targeted to quality, efficiency and state needs.
12. The state places a high priority on an education *system* of schools, colleges and universities that is accountable.

The Southern Regional Education Board has established these Goals for Education, which challenge SREB states to lead the nation in educational progress. They are built on the groundbreaking education goals SREB adopted in 1988 and on more than a decade of efforts to promote actions and measure progress.

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