9TH GRADE-12TH GRADE

# Science as Inquiry

**Content Standard A:**

**As a result of activities in grades 9-12, all students should develop**

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

# Content Summary

## National Science Education Content Standards

### K-4

**Abilities necessary to do scientific inquiry**

**Understandings about scientific inquiry**

### 5-8

**Abilities necessary to do scientific inquiry**

**Understandings about scientific inquiry**

### 9-12

**Abilities necessary to do scientific inquiry**

**Understandings about scientific inquiry**

## Minnesota Graduation Standards

### Primary Level

**Data Categorization, Classification and Recording:**

Gather information to answer questions

**Writing and Speaking:**

Write and speak for a variety of academic and technical purposes

**Shape, Space and Measurement:**

Apply concepts of shape, space, and measurement to solve problems involving two- and three-dimensional shapes

### Intermediate Level

**Media, Observation and Investigation:**

Answer questions using information gathered through direct observations, experiments, and other sources

**Chance/Data Handling:**

Apply concepts of chance & data analysis to evaluate information and solve problems in a familiar context

**Speaking:**

Speak to an audience or interact with a group

### Middle Level

**Controlled Experiments:**

Design and conduct a controlled experiment or investigation and interpret the results

**Direct Observation:**

Gather information to answer scientific or social science questions

**Patterns and Functions:**

Analyze patterns and use concepts of algebra to represent mathematical relationships

**Chance/Data Handling:**

Apply concepts of chance and techniques of data handling to evaluate and solve problems

### High School Level

In each of the standards the student selects within the *Scientific Applications* Learning Area, the student must demonstrate understanding and application of scientific investigation

# Focus K-12

| Grade | Early | Late |
|---|---|---|
| K-4 | The focus of instruction early in this grade range is on engaging all students in teacher-guided experiences that develop the ability to ask questions, make observations, use simple tools to investigate, collect data, and communicate their findings. | The focus of instruction later in this grade range is on engaging all students in teacher-guided experiences that develop the ability to ask scientific questions, design and construct simple experiments, and communicate reasonable explanations. |
| 5-8 | The focus of instruction early in this grade range is on providing all students with an environment that stimulates students to ask their own scientific questions within the context of the curriculum, and assisting them as they design, carry out, analyze, and communicate findings from their own investigations. | The focus of instruction later in this grade range is on providing all students with opportunities to participate in full and partial inquiry activities which challenge them to apply their science knowledge, understandings, and abilities as they carry out more complex investigations and communicate results. |
| 9-12 | The focus of instruction at the high school level is on providing all students with the opportunity to develop an understanding of the nature of scientific inquiry through active participation in full, meaningful inquiry investigations directed toward learning scientific content. | The focus of instruction for students pursuing further study is on providing opportunities to participate in independent exploration of sophisticated content using the abilities and understandings of inquiry. |

# Close-up 9-12

The focus of instruction at the high school level is on providing all students with the opportunity to develop an understanding of the nature of scientific inquiry through active participation in full, meaningful inquiry investigations directed toward learning scientific content.

All high school students continue to develop their understanding of inquiry as well as abilities to inquire scientifically. As students' inquiry abilities become more sophisticated, their investigations become increasingly less teacher dependent. While the teacher identifies outcomes for a unit of study, students take more responsibility for gathering background information, designing and conducting investigations, determining tools and materials needed, and making sense of the data. The teacher's role varies — coach, facilitator, director, cheerleader, critic, sometimes even co-investigator. The teacher and students meet frequently to monitor progress, discuss repeating or revising data collection procedures and analysis, and discuss explanations, evidence, and applications. Students may work alone as well as in small or large groups. Throughout an investigation, appropriate technological tools are used to access, communicate, analyze, and display information. Results are reported in various forms for review by teacher and/or classmates. Often additional questions arise from the investigation which result in new questions and investigations, and the inquiry process begins again. Students and teachers observe established science safety procedures.

The focus of instruction for students pursuing further study is on providing opportunities to participate in independent exploration of sophisticated content using the abilities and understandings of inquiry.

Students pursuing further study in science develop sophistication in their abilities and understandings of scientific inquiry. Although the teacher may help define the questions to be investigated, students engage in individual and group investigations on topics of their choice. Students use outside resources, including print and electronic sources, to assist them in determining questions to be investigated, developing procedures, designing equipment, determining variables and controls, and designing data collection and analysis methods. Teacher discussions with the students are collegial and they are used to ensure that students benefit fully from the inquiry experience. Students often develop mathematical models as a part of their explanations. Classroom forums can be used to discuss results, inconsistencies in data, sources of experimental error, and alternative explanations. Textbooks and other sources, often original research papers, are checked to compare theory with the results of the students' investigations. Student abilities and understandings allow them to work independently in a supporting environment as they investigate these concepts. Students and teachers observe established science safety procedures.

# On Location 9-12

*This is an example of students participating in full inquiry in a regular science course. Class time is provided for students to formulate questions, design and conduct scientific investigations, and report their results to peers as well as other audiences. All of this is done under teacher supervision and guidance.*

"All my students participate in a research project," says Ms. Z, a high school biology teacher. Her students ask a scientific question about something that interests them, design and conduct investigations, recognize and analyze alternative explanations, use technology throughout their process, and communicate and defend their findings. The projects are individualized to fit the needs and interests of each student in her class.

Students choose their topics after reviewing abstracts from Biology Digest, looking at titles from regional and state science fair programs as well as scientific journal articles that are available in the classroom. Some students may investigate topics they have heard or read about in the media. After selecting a general topic, students narrow their topics to specific "what would happen if..." questions.

Ms. Z sees her role as one of guiding. While she supports and helps her students, she expects them to take the initiative to use the phone to order their own supplies, contact experts to find background information or mentors, and if needed, find specialized laboratory equipment or facilities. As one can imagine, the variety of student projects is wide. In any one year Ms. Z's students may investigate the personal—protein buildup on contact lenses, or the societal—nitrogen runoff into the nearby river. While Ms. Z supervises her students in every phase of their projects, she limits her participation to asking clarifying questions, ensuring a safe working environment, and suggesting resources.

Once each year, parents, faculty, and community members are invited to a science symposium where students give poster presentations on their projects. The final challenge for these students is to explain their research to the visitors. Ms. Z believes that oral communication is a critical skill for students to learn and practice. The symposium is not bad P.R. for the science program either.

# National Science Education Content Standards

## 9-12 Content Standard A

**Abilities Necessary to do Scientific Inquiry**

- **Identify questions and concepts that guide scientific investigations.** Students should formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding a hypothesis and the design of an experiment. They should demonstrate appropriate procedures, a knowledge base, and conceptual understanding of scientific investigations.
- **Design and conduct scientific investigations.** Designing and conducting a scientific investigation requires introduction to the major concepts in the area being investigated, proper equipment, safety precautions, assistance with methodological problems, recommendations for use of technologies, clarification of ideas that guide the inquiry, and scientific knowledge obtained from sources other than the actual investigation. The investigation may also require student clarification of the question, method, controls, and variables; student organization and display of data; student revision of methods and explanations; and a public presentation of the results with a critical response from peers. Regardless of the scientific investigation performed, students must use evidence, apply logic, and construct an argument for their proposed explanations.
- **Use technology and mathematics to improve investigations and communications**. A variety of technologies, such as hand tools, measuring instruments, and calculators, should be an integral component of scientific investigations. The use of computers for the collection, analysis, and display of data is also a part of this standard. Mathematics plays an essential role in all aspects of an inquiry. For example, measurement is used for posing questions, formulas are used for developing explanations, and charts and graphs are used for communicating results.
- **Formulate and revise scientific explanations and models using logic and evidence.** Student inquiries should culminate in formulating an explanation or model. Models should be physical, conceptual, and mathematical. In the process of answering the questions, the students should engage in discussions and arguments that result in the revision of their explanations. These discussions should be based on scientific knowledge, the use of logic, and evidence from their investigation.
- **Recognize and analyze alternative explanations and models.** This aspect of the standard emphasizes the critical abilities of analyzing an argument by reviewing current scientific understanding, weighing the evidence, and examining the logic so as to decide which explanations and models are best. In other words, although there may be several plausible explanations, they do not all have equal weight. Students should be able to use scientific criteria to find the preferred explanations.
- **Communicate and defend a scientific argument.** Students in school science programs should develop the abilities associated with accurate and effective communication. These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments.

# National Science Education Content Standards

## 9-12 Content Standard A (continued)

**Understandings About Scientific Inquiry**

- Scientists usually inquire about how physical, living, or designed systems function. Conceptual principles and knowledge guide scientific inquiries. Historical and current scientific knowledge influence the design and interpretation of investigations and the evaluation of proposed explanations made by other scientists.
- Scientists conduct investigations for a wide variety of reasons. For example, they may wish to discover new aspects of the natural world, explain recently observed phenomena, or test the conclusions of prior investigations or the predictions of current theories.
- Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used.
- Mathematics is essential in scientific inquiry. Mathematical tools and models guide and improve the posing of questions, gathering data, constructing explanations and communicating results.
- Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge.
- Results of scientific inquiry—new knowledge and methods—emerge from different types of investigations and public communication among scientists. In communicating and defending the results of scientific inquiry, arguments must be logical and demonstrate connections between natural phenomena, investigations, and the historical body of scientific knowledge. In addition, the methods and procedures that scientists used to obtain evidence must be clearly reported to enhance opportunities for further investigation.

# Scientific Applications

## General Note

**Scientific Applications**

In each of the standards the student selects within the *Scientific Applications* Learning Area, the student must demonstrate understanding and application of scientific investigation, including:

**Knowing:**

a. How historical and current scientific concepts and knowledge guide inquiries;
b. That experiments are performed to test ideas and predictions and to learn about the natural world;
c. That the use of various technologies influence the quality of data and the investigation;
d. That mathematical tools and models are essential to scientific inquiry;
e. That explanations are based on evidence and adhere to established criteria such as empirical standards, logic, openness to criticism, and reporting of methods and procedures; and
f. What traditions govern the conduct of science, including ethics, peer review, and consensus; and

**Demonstrating the ability to:**

a. Formulate questions and hypothesis;
b. Describe methodology and conduct investigation;
c. Record relevant data;
d. Analyze data using statistical methods;
e. Construct reasonable explanations to answer the question and support or refute the hypothesis;
f. Identify and consider alternative interpretations of results; and
g. Specify implications for further investigation.