Science as Inquiry

Content Standard A:

As a result of activities in grades 5-8, 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 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.

Students engage in full and partial inquiry activities where they ask questions, design investigations, gather evidence to answer their original questions, and display and communicate their results. In some cases, an entire class may investigate the same question, in other cases, cooperative groups or individuals investigate different questions and share their processes and results with their peers. In either case, teachers assist students as they define scientific questions to be investigated. Guided by the teacher, students determine what observations and data they will need to collect, and what tools and materials they will need to use. Throughout the inquiry process, the teacher encourages students, suggests when they need to repeat or revise their procedures, and advises them on accurate measurement and observation techniques. Investigations should be simple, emphasizing "fair tests" with only one variable changed at one time. At this age level, the teacher must work closely with students as they analyze their results to ensure that their explanations reflect the data collected. Students and teachers observe established science safety procedures.

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.

As students begin to understand that content knowledge and scientific theories guide the design of investigations, the types of observations made, and the interpretation of data, their investigations become more sophisticated. They engage in teacher directed experiences that allow them to develop enough knowledge in a content area to ask meaningful questions which can be investigated. To help students focus questions and investigations, teachers encourage them to ask, "What are the best observations or measurement to make?", "How can we make the most accurate measurements?", "If we do that, what do we expect will happen?", and "Is this the best way to answer our question?" At this age students do experiments where they manipulate one or two variables and may have difficulty understanding the influence of many different variables in an experiment, especially ones that have no effect, marginal effect, or opposite effects on the results. They gather and interpret data quantitatively, using basic mathematical concepts. During the inquiry process, the teacher encourages and suggests when they need to repeat or revise their data collection procedures, and advises them on accurate measurement and observation techniques. Computers and other technological tools are used to access information and analyze data. Because students at this age tend to focus on evidence that confirms their own beliefs and ignore evidence that does not agree, the teacher must work closely with students to ensure that explanations are supported by evidence and to help them consider alternative explanations. Students communicate their results in various forms. Students and teachers observe established science safety procedures.

On Location 5-8

Here, students investigate a Cartesian Diver System. There are aspects of this unit that they may not fully understand, such as density, but as they isolate variables and use a fair test, a foundation for understanding density is laid that will be developed later on.

Mr. G, a middle school teacher, is about to demonstrate a Cartesian diver. His diver is floating in a flat-sided bottle, and it falls only when Mr. G rubs a nine-volt transistor radio battery up and down on the side of the bottle. He asks, "What do you see?" While many of the class observations are rather far fetched, all of them are taken at face value and are used to discuss differences between observations and explanations.

After the initial demonstration, Mr. G has the students test their explanations. Groups of students investigate with their own bottles and batteries, and discover that the battery has no effect, but the diver falls when the bottle is squeezed. Now they want to know why squeezing a bottle causes the diver to move. Mr. G's students write down all their ideas that can be tested.

Working in small groups, students put their ideas to a test. They make careful observations of the Cartesian diver and note that the amount of water in the diver changes as it moves to the bottom of the bottle. Does squeezing the bottle somehow push more water into the diver, causing it to sink?

Mr. G works with the students to develop a common format for organizing their data that enables them to compare their results and make judgments from them. During class discussion of their results, Mr. G asks them to propose explanations and defend them with the data that was collected. Next, they test their explanations by constructing their own Cartesian Diver.

While many of Mr. G's students may not fully grasp the concept of density, they begin to understand the dynamics taking place inside the bottle and diver as the bottle is squeezed, which will contribute to their understanding of density. The students also recognize the difference between explanations and evidence, can identify questions that can be answered through scientific investigations, and are able to practice designing and conducting their own scientific investigations.

National Science Education Content Standards

5-8 Content Standard A

Abilities Necessary to do Scientific Inquiry

- **Identify questions that can be answered through scientific investigations.** Students should develop the ability to refine and refocus broad and ill-defined questions. An important aspect of this ability consists of students' ability to clarify questions and inquiries and direct them toward objects and phenomena that can be described, explained, or predicted by scientific investigations. Students should develop the ability to identify their questions with scientific ideas, concepts, and quantitative relationships that guide investigation.
- **Design and conduct a scientific investigation.** Students should develop general abilities, such as systematic observation, making accurate measurements, and identifying and controlling variables. They should also develop the ability to clarify their ideas that are influencing and guiding the inquiry, and to understand how those ideas compare with current scientific knowledge. Students can learn to formulate questions, design investigations, execute investigations, interpret data, use evidence to generate explanations, propose alternative explanations, and critique explanations and procedures.
- **Use appropriate tools and techniques to gather, analyze, and interpret data.** The use of tools and techniques, including mathematics, will be guided by the question asked and the investigations students design. The use of computers for the collection, summary, and display of evidence is part of this standard. Students should be able to access, gather, store, retrieve, and organize data, using hardware and software designed for these purposes.
- **Develop descriptions, explanations, predictions, and models using evidence.** Students should base their explanation on what they observed, and as they develop cognitive skills, they should be able to differentiate explanation from description—providing causes for effects and establishing relationships based on evidence and logical argument. This standard requires a subject matter knowledge base so the students can effectively conduct investigations, because developing explanations establishes connections between the content of science and the contexts within which students develop new knowledge.
- **Think critically and logically to make the relationships between evidence and explanations.** Thinking critically about evidence includes deciding what evidence should be used and accounting for anomalous data. Specifically, students should be able to review data from a simple experiment, summarize the data, and form a logical argument about the cause-and-effect relationships in the experiment. Students should begin to state some explanations in terms of the relationship between two or more variables.
- **Recognize and analyze alternative explanations and predictions.** Students should develop the ability to listen to and respect the explanations proposed by other students. They should remain open to and acknowledge different ideas and explanations, be able to accept the skepticism of others, and consider alternative explanations.
- **Communicate scientific procedures and explanations.** With practice, students should become competent at communicating experimental methods, following instructions, describing observations, summarizing the results of other groups, and telling other students about investigations and explanations.
- **Use mathematics in all aspects of scientific inquiry.** Mathematics is essential to asking and answering questions about the natural world. Mathematics can be used to ask questions; to gather, organize, and present data; and to structure convincing explanations.

National Science Education Content Standards

5-8 Content Standard A (continued)

Understandings About Scientific Inquiry

- Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.
- Current scientific knowledge and understanding guide scientific investigations. Different scientific domains employ different methods, core theories, and standards to advance scientific knowledge and understanding.
- Mathematics is important in all aspects of scientific inquiry.
- Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.
- Science advances through legitimate skepticism. Asking questions and querying other scientists' explanations is part of scientific inquiry. Scientists evaluate the explanations proposed by other scientists by examining evidence, comparing evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations.
- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations.

Minnesota Graduation Standards

Intermediate Level

Media, Observation and Investigation:

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

What students should do:

1. Gather information from direct observations or experiments with a variable:
   a. frame a question
   b. collect, record and display data
   c. identify patterns
   d. compare individual findings to large group findings
   e. identify areas for further investigation
2. Gather information from media sources:
   a. select a topic and frame a question
   b. access information from electronic media, print, interviews and/or other sources
   c. record and organize information
   d. report findings in written, oral or visual presentation
3. Gather information through direct observation and interviews:
   a. identify a topic or area for investigation
   b. write a rich and detailed description of the observation
   c. conduct an interview with follow-up questions or design and conduct a survey
   d. record and organize information
   e. evaluate the findings to identify areas for further investigation

In Addition:

1. Use appropriate technology to handle and display data.
2. Provide guidelines for topic selection, number, variety, and types of sources as well as organization of information.
3. Tasks may be combined with standards in Writing and Speaking in order to communicate findings.
4. Students must demonstrate basic safety procedures and skills when using tools and equipment.

Chance and Data Handling:

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

What students should know:

1. Understand how to find range, mean and median
2. Understand simple concepts of likelihood: impossible, unlikely, equal chance, likely, certain, fair and unfair
3. Understand information displayed in graphs, tables and charts

What students should do:

1. Answer questions:
   a. collect and organize data
   b. represent data (e.g., graphs, charts)
   c. communicate results
2. Conduct experiments involving uncertainty (e.g., use spinners, number cubes, M&M's)
   a. list possible outcomes
   b. tally, record, and explain results
   c. use the results to predict future outcomes
3. Describe patterns, trends or relationships in data displayed in graphs, tables and/or charts
4. Represent data using at least two graphic forms (e.g., graphs, tables, charts, pictures)

In Addition:

Performance package must use one or more forms of technology.

Speaking:

Speak to an audience or interact with a group.

What students should do:

1. Plan and carry out an event in a small group:
   a. construct a flow chart of work to be done
   b. implement a group work plan
   c. demonstrate a variety of cooperative group roles in discussion situations
   d. take responsibility for obtaining, organizing and using materials
2. Prepare and give a demonstration to an audience:
   a. describe a step-by-step procedure to complete an action
   b. use visuals or manipulatives to illustrate ideas
   c. demonstrate effective delivery techniques (e.g., eye contact, appropriate volume, appropriate expression)
   d. answer questions from audience concerning demonstration

In Addition:

Consider cultural differences affecting interpersonal and personal communication styles when constructing performance tasks.

Minnesota Graduation Standards

Middle Level

Controlled Experiments:

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

What students should do:

1. Given a topic, use relevant information to generate a hypothesis or frame a question
2. Define the control(s), variable and sample size (or number of repetitions)
3. Set up a method to test the hypothesis
4. Determine how to record and organize data
5. Conduct experiment and record data
6. Analyze data and evaluate hypotheses
7. Identify areas for further investigation

In Addition:

1. Use appropriate technology to handle and display data.
2. Teachers may give feedback on each step of the process.
3. Students may work in small groups.

Patterns and Functions:

Analyze patterns and use concepts of algebra to represent mathematical relationships.

What students should know:

1. Understand the concepts of variables, expressions and equations

What students should do:

1. Recognize, analyze and generalize patterns found in:
   a. linear and non-linear phenomena
   b. data from lists, graphs and tables
   c. number theory
   d. sequences
   e. rational numbers
   f. formulas
2. Represent and interpret cause and effect relationships using:
   a. algebraic expressions
   b. equations and inequalities
   c. tables and graphs
   d. verbal descriptions
   e. spread sheets
3. In problem situations:
   a. connect verbal, symbolic and graphical representations
   b. identify constraints
   c. translate algebraic expressions into equivalent forms
   d. propose and justify solutions
4. Use properties of mathematics to informally justify reasoning in a logical argument

In Addition:

1. Performance package must include at least one form of technology.
2. Embed communication, problem solving, connections and reasoning in performance task.

Direct Observation:

Gather information to answer scientific or social science questions.

What students should do:

1. Gather information from direct observations:
   a. frame a question
   b. collect and record data
   c. display data in appropriate format (e.g., graphs, tables, charts, diagrams)
   d. look for patterns in observable data
   e. relate findings to new situations or large group findings
   f. answer a question or present a position using data
   g. identify areas for further investigation
2. Gather information through direct observation, interviews or surveys:
   a. frame a question
   b. collect data through observation, interviews or surveys
   c. record and organize information
   d. evaluate the question based on findings

In Addition:

1. Teachers may help students define and limit research questions.
2. Students may work independently or in groups.

Chance and Data Handling:

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

What students should know:

1. Calculate basic measures of center and variability (e.g., mean, median, mode, range, quartiles)
2. Understand basic concepts of probability (e.g., experimental/theoretical, 0- 1 scale, random, sampling, outcomes, fairness)
3. Calculate simple probabilities

What students should do:

1. Formulate a question and design an appropriate data investigation
2. Organize raw data and represent it in more than one way
3. Analyze data by selecting and applying appropriate data measurement concepts (e.g., measure center, variability)
4. Critique various representations of data
5. Devise and conduct a simulated probability situation
6. Predict future results based on experimental results

In Addition:

1. Performance package must include at least one form of technology.
2. Embed communication, problem solving, and reasoning in performance task