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Science Inquiry:
The Link to Accessing the General Education Curriculum

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What is Inquiry?

Inquiry is an interactive process that actively engages students in learning in meaningful ways. The process of inquiry is characterized by interactive, student-centered activities focused on questioning, exploring, and posing explanations. The goal of inquiry is to help students gain a better understanding of the world around them through active engagement in real-life experiences.

How does Inquiry compare with the scientific method?

While inquiry can be incorporated into all content areas, it is most commonly implemented in science classrooms. Why is inquiry important in science classrooms? The process of inquiry not only enhances students' understanding of natural phenomena, but also develops students' science process skills. It is a nonlinear variation of the scientific method. Composed of the same basic components, both the scientific method and the inquiry process require students to conduct research investigations by formulating a question, developing a hypothesis, conducting an experiment, recording data, analyzing data, and drawing conclusions (see Table 1 below).

Table 1

Scientific Method and Inquiry Process

Scientific Method	Inquiry Process
Question or problem	Inquiry phase (inquiry or problem)
Hypothesis	
Experiment	Data gathering phase I (hypothesis)
Record	
Data analysis	Data gathering phase II (data collection & analysis)
Conclusion	
	Implementation phase (conclusion & explanations)

The major difference between the scientific method and the inquiry process is that the inquiry process provides more opportunities to move within and among the phases of the inquiry (problem-solving process). Students can enter the inquiry process at any of the four phases. Generally, students new to this process begin at the inquiry phase (see Figure 1). They use teacher-guided questions and investigation protocols to develop their questions and inquiries. Students more familiar with the process are able to extend learning by beginning their inquiry at other phases. For example, these students may begin the process by reviewing data (data gathering phase I)—for example, a bar chart on weather patterns or population genetics—and then, based on the data, identifying a research question or inquiry for further investigation (inquiry phase).

The inquiry process has multiple points of entry (as shown in Figure 1). Eventually, however, students will go through each phase in order to conduct a thorough investigation. At that point, the inquiry process and scientific method converge.

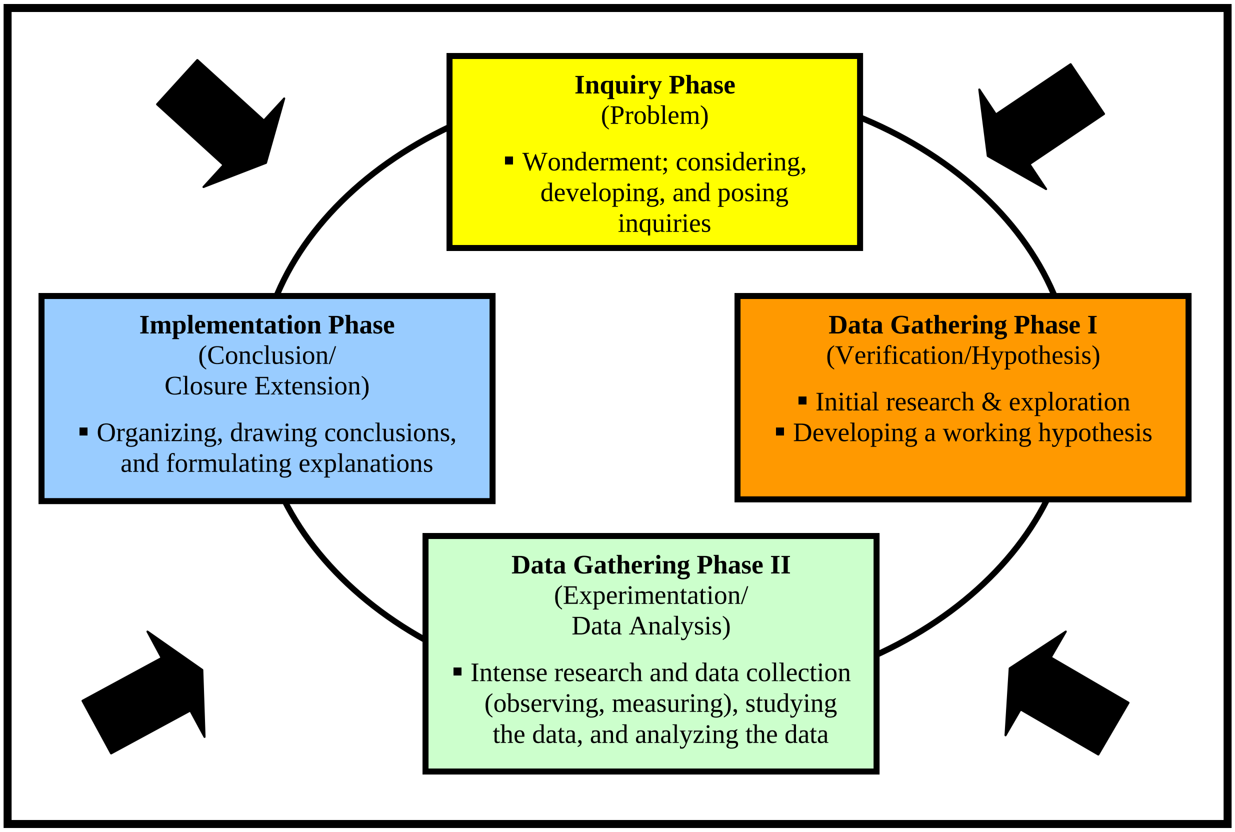

Figure 1. Phases of Inquiry

Science teachers generally like the inquiry process because it targets the eight science process skills that all students are expected to master in science classrooms. These skills include: (a) make observations; (b) conduct experiments; (c) collaborate with others about investigations; (d) take measurements; (e) sort and classify (i.e., organisms, types of substances, etc.); (f) compare and contrast; (g) record findings; (h) analyze findings; and (i) share their results with others (see Table 2). To ensure that students develop these skills, science lessons often focus on a specific science process skill. For instance, students may spend an entire class period learning to classify different types of rocks. Another science lesson may require students to analyze a graph depicting monarch butterfly migratory patterns.

Table 2

Science Process Skills

Science Process Skills	
Observe	Sort/Classify
Experiment	Compare
Collaborate	Record
Measure	Analyze & Share

Although each science process skill is often taught separately, students should also be offered opportunities to learn and apply more than one process skill at a time. The inquiry process provides opportunities for students to develop and enhance all of their science process skills through a single research investigation.

What does inquiry look like in science classrooms?

Students in inquiry-based classrooms are provided hands-on opportunities to engage in science investigations using a more holistic variation of the scientific method. With teachers serving as "facilitators of learning," inquiry-based science often consists of team projects, collaboration, student-led investigations, and outdoor explorations. Students raise questions, pose hypotheses, research and experiment, analyze their data, and provide plausible (evidence-based) explanations.

Because of the importance of the inquiry process, the National Science Education Standards (NSES) recognizes "science as inquiry" as a critical content standard all students must master before they graduate from high school. According to the NSES (National Academy Press, 1996), inquiry-based classrooms should include:

> A multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

Because they are student-driven and interactive, inquiry-based classrooms are generally more active, physically and intellectually, than traditional science classrooms.

What is the role of science teachers in inquiry-based classrooms?

Teachers serve as "facilitators of learning" in inquiry-based classrooms, guiding students through the inquiry process. To foster this type of learning environment, teachers use three types of inquiry in science: structured, guided, and open (see Table 3). There is debate as to which type of inquiry is best. The general consensus is that any form of inquiry (structured, guided, or open) can be useful to students when taught appropriately and well.

*Structured inquir*y is the most teacher-centered of the three types of inquiry. This type of inquiry is commonly seen in science classrooms in the form of laboratory exercises. The teacher provides fairly structured procedures for the inquiry activity, and students carry out the investigations. Structured inquiry could be described as the most traditional approach to inquiry.

On the far side of the spectrum is *open inquiry*. This type of inquiry requires the least amount of teacher intervention and is student led. Students often work in groups and plan all phases of the investigations. This is the purest form of inquiry conducted in science classrooms (see Table 3).

Guided inquiry falls in the middle of the inquiry instructional spectrum. This approach is commonly used when students are asked to make tools or develop a process that results in a desired outcome. For example, a science teacher gives her seventh grade middle school students materials to create a rocket but no instructions for designing the rocket. The students must use their own knowledge and creativity to design the rocket so that it will launch properly, fly a certain distance, and land without becoming disassembled. The teacher provides the problem and materials and the students develop the rocket using their own scientific process or procedure.

Teachers and classrooms new to inquiry often begin with structured inquiry activities and transition to more open inquiry activities. Moving gradually from structured classrooms to open-inquiry classroom environments is often less overwhelming. Radical changes can be frustrating and upsetting to some students, particularly because inquiry-based classrooms are typically more student centered. Students in inquiry-based settings are more actively involved in their discovery and subsequently more responsible for their learning. Teachers using inquiry-based instruction play more of a “facilitator of learning” role than teachers in traditional settings. Teachers and students may need practice to get comfortable with learning experiences that require less guidance and fewer teacher interventions.

What are some considerations for implementing inquiry in science?

Teachers can foster better experiences with inquiry in various ways and ultimately positively affect students’ science process skills and understanding of science. Whether the inquiry activity is structured, guided, or open, these suggestions can help alleviate students’ fears about doing inquiry and build their science process skills, as well as help them learn science concepts.

Table 3

Types of Inquiry Used in Science Classrooms

Type of Inquiry	Description	Example
Structured	Teacher gives students problems to investigate during hands-on activities, as well as procedures and materials. Students must determine the outcome.	Laboratory activities with procedures, materials, and questions specified.
Guided	Teacher gives students the problem or question and materials. Students have to determine the process and outcome.	Students are given a hard-boiled egg and paper supplies. Students are asked to create a device using the supplies that will protect the egg when it is dropped from a five-story building.
Open	Students determine the problem, investigation, procedure, and outcome.	Students take a field trip to a vegetable garden. Students are given several minutes to explore the garden. Working with a partner, students must identify a researchable problem and conduct an investigation based on their observations. For example, which vegetables grow best in shade?

When implementing inquiry in science, keep the following in mind:

- Ask open-ended questions
- Allow wait time after asking questions
- Avoid telling students what to do
- Avoid rejecting and/or discouraging student ideas or behaviors
- Encourage students to find solutions on their own
- Encourage collaboration among students
- Maintain high standards and order
- Develop and use inquiry-based assessments to monitor students' progress
- Know that inquiry can be challenging for some students and be prepared to provide more guidance to those students when signs of frustration appear (Institute for Inquiry, 1995; Washington Virtual Classroom, 2005)

Why is inquiry important for teaching and learning science?

Inquiry allows students to learn and experience science firsthand, by taking on the roles of scientists. Like scientists, students use the inquiry process to develop explanations from their observations (evidence) by integrating what they already know with what they have learned. They learn discrete science concepts and skills, and how to solve problems using practical approaches—the goal of science education.

Incorporating inquiry into science classrooms empowers students. They play an active role in their learning rather than the passive role commonly seen in traditional science classrooms. This self-empowerment positively affects students' perceptions about science. According to the Institute for Inquiry (2005), students doing inquiry-based science:

- View themselves as scientists in the process of learning
- Accept an "invitation to learn" and readily engage in the exploration process
- Plan and carry out investigations
- Communicate using a variety of methods
- Propose explanations and solutions and build a store of concepts
- Raise questions
- Use observations
- Critique their science practices

Opportunities to think and behave as scientists provide relevancy and credibility to students' understanding of science. They learn that it is appropriate to ask questions and seek answers. In addition, students learn the challenges and pitfalls of investigations.

Lastly, positive research findings have provided further reasons for implementing inquiry into science classrooms. Mattheis and Nakayama (1988) found that inquiry-based programs at the middle school grades have been found to generally enhance student performance, specifically performance related to science process skills, laboratory skills, graphing skills, and data interpretation. Another study found that inquiry-based science instruction can be effective in promoting scientific literacy and a better understanding of science processes in students from diverse backgrounds (Cuevas, Lee, Hart, & Deaktor, 2005). Ruffin (2003) found increases in science interest and improvements in the science process skills among middle school students doing inquiry-based science in a technology-supported learning environment. Numerous other research studies indicate positive outcomes for inquiry-based science (Krajcik et al., 1998; White & Fredericksen, 1998).

How can Inquiry be Applied for Students with Learning Disabilities?

A learning disability (LD) is usually associated with students who do not develop skills in a way that is commensurate with their potential (Lyon et al., 2001). LD is not a specific disability itself, but is a general category of disability composed of disabilities in any combination of the following skills: listening, speaking, basic reading, reading comprehension, arithmetic calculation, mathematic reasoning, and written expression (Lyon et al., 2001). Disabilities in the skills mentioned above can affect performance in the science classroom where students are required to listen, speak, and apply reading, writing, and mathematics skills. Specifically, LD can affect a student's experience in a science classroom that uses an inquiry approach.

There is a small body of research on students with LD in an inquiry classroom. A study by Scruggs, Mastropieri, Bakken, and Brigham (1993) suggests that students with LD who learn through an inquiry-oriented approach, rather than through a textbook-based approach, perform better on unit tests. Bay, Staver, Bryan, and Hale (1992) compared the effectiveness of direct instruction and discovery teaching, where students were actively engaged in gathering data, generating and implementing solutions, and observing their consequences with the science achievement of students with mild disabilities and students without disabilities. The researchers found that students' retention after 2 weeks was higher for those who received discovery instruction. Results also indicated that students with learning disabilities who received discovery instruction outperformed students with learning disabilities who received direct instruction. Evidence also exists suggesting that this approach leads to higher achievement for students with learning disabilities than an activity-based approach alone (Dalton & Morocco, 1997).

Researchers have examined the characteristics of students with learning disabilities, and connections can be made between these characteristics and strategies that may help students access an inquiry-based curriculum. In addition, the student-centered nature of inquiry allows teachers the flexibility to tailor instruction to meet the diverse learning needs that students with LD bring to the classroom. Table 4 helps to make these connections by providing implications for access to inquiry for students with LD at each phase of inquiry, as well as strategies to support these students in an inquiry-based classroom. Many of the strategies listed are linked to a resource or Web site that can provide more information.

Table 4

Strategies to Support Students With Learning Disabilities During Phases of Inquiry

Phase of Inquiry	Implications for Access for Students With LD	Strategies to Support Students with LD
Inquiry Phase Requires student to consider the topic at hand and to pose questions	Students with LD may have difficulty linking new concepts and vocabulary to familiar ideas,[1] which can affect their ability to understand a new topic and therefore pose questions about it. Students with LD may have difficulty with expressive language,[2] which may affect their ability to articulate questions or inquiries about a topic. If students have an LD in written language, they may have difficulty expressing ideas in written form. Abstract concepts may need to be made more concrete[3] for students with LD.	Mnemonics improves memory by linking new information to current knowledge through visual and verbal cues. Mnemonics, used in a laboratory setting, can help students learn vocabulary,[4] which can lead to better comprehension of science topics. Graphic organizers, which provide a pictorial representation of concepts, can help students with LD see the connection among ideas and draw conclusions that will help them pose questions. Graphic organizers can also make abstract concepts more concrete for students. Peer tutoring can lead to improved academic achievement in content areas.[5]
Data Gathering Phase I (Verification /Hypothesis) Requires students to conduct initial stages of research and exploration and to propose a working hypothesis	Students with LD may have difficulty with logical reasoning which can impact their ability to predict.[6] Selective attention difficulties in some students with LD can lead them to focus on only one part of a problem,[7] which may affect their ability to see the "big picture" when proposing hypotheses.	Use graphic organizers to help students with LD organize steps during initial stages of research, and to organize initial data collection, helping to connect ideas so that a hypothesis can be formed. Consider the use of assistive technology (AT), which can provide support for students as they collect and record data and may help them express their working hypothesis. Use a "think-pair-share" strategy allowing students to come up with their own hypothesis, compare their hypothesis with those of peers,

1 Bell, 2002
2 Rock & Fessler, 1997
3 Lenz & Schumaker, 1999
4 Mastropieri & Scruggs, 1992
5 Cohen, Kulik & Kulik, 1982; Cook, Scruggs, Mastropieri, & Casto, 1985; Johnson, Maruyama, Johnson, Nelson & Skon, 1981
6 Bell, 2002
7 Hardman et al., 1993

Phase of Inquiry	Implications for Access for Students With LD	Strategies to Support Students with LD
		and share a jointly developed hypothesis. Grouping strategies can provide appropriate academic models and support from other students. Teachers can model and teach metacognitive skills and demonstrate how to think through a problem. Allow students to visually represent the problem and hypothesis. Ask students questions that activate prior background knowledge and allow them to make new connections to concepts that are already familiar. Teaching students cognitive strategies, such as note-taking, outlining, and questioning, may help them organize data.
Data Gathering Phase II (Experimentation/ Data Analysis) Requires students to engage in intense research and data collection (observing, measuring), to study the data, and to analyze the data.	Students with LD may have difficulty selecting, implementing, and adjusting strategies for problem solving.[8] Students with LD may have difficulty focusing on a task over a sustained period of time.[9] This can affect their ability to complete an inquiry investigation during an extended block of time. Students with LD may have difficulty with visual perception and discrimination, which might lead to errors while looking at data.[10] Students with an LD in mathematics	Students with LD should be taught new skills in a systematic manner that involves continued practice and teacher guidance[11] so that instruction is scaffolded. AT and the use of computer programs can assist students with organizing and analyzing data and may also help students who have difficulty with selective attention. Teach students to independently check work, ask for help, as clarifying questions, or redo work if necessary.[12] These skills should be directly taught and modeled for students with LD. Teach students note-taking strategies, such as

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[8] Torgesen, 1994
[9] Bell, 2002
[10] Hardman et al., 1993
[11] Rock et. al, 1997
[12] Lenz & Schumaker, 1999

Phase of Inquiry	Implications for Access for Students With LD	Strategies to Support Students with LD
	may need support with data analysis and interpretation. Selective attention difficulties may impact a student with LD's ability to control variables during an investigation (for example, identifying all variables and keeping all but the tested variable unchanged).	two-columned notes, that provide ways to record data. Schedule data collection in several shorter time blocks rather than one longer time block. This will give students time to process what they have already done and allow them to maintain focus on the task. Allow students to speak their data collection notes into a tape recorder rather than writing them down.
Implementation Phase (Conclusion/ Closure/ Extension) Requires the student to organize data and analysis, draw conclusions, and formulate explanations.	Students with LD may have difficulty with logical reasoning, which can impact their ability to infer and problem solve.[13] Students with LD may have a tendency toward becoming over-reliant on the opinions of others and reluctant to use their own judgment,[14] which can affect their ability to draw their own conclusions, particularly in group work situations. Students with LD who have comprehension difficulties may also have difficulties constructing inferences.[15]	Using hands-on activities during inquiry lessons can provide positive experiences for students with LD, leading to increased confidence in their own ability,[16] which may help students feel more confident about drawing their own conclusions. Asking students questions that activate related background knowledge may assist students with comprehension tasks,[17] which may in turn help them with constructing inferences. Teachers can model thinking processes for students to show them how they use data to draw conclusions. Offer students a variety of options for their predictions and conclusions so that they can begin learning the process by selecting the best choice. Eventually students will move to creating their own predictions. Students may need additional time to examine data several times and revisit previous ideas or

[13] Bell, 2002
[14] Bell, 2002
[15] Wise & Snyder, 2002
[16] Bell, 2002
[17] Billingsley & Wildman, 1988

Phase of Inquiry	Implications for Access for Students With LD	Strategies to Support Students with LD
		concepts before drawing conclusions. Graphic organizers can help students organize data and provide a visual representation of connections among ideas.

Conclusion

Incorporating inquiry into science classes takes time and effort, but the rewards are numerous. The inquiry process is active, engaging, and transferable. Studies have found that not only are students learning more science content through inquiry, but they are also developing the ability to “study the natural world and propose explanations based on the evidence derived from their work” through inquiry (NAP, 1996).

Students with LD can be active participants in and benefit from instruction in an inquiry-based classroom as well. It is essential, however, that these students are provided with direct instruction, classroom supports, and a guided process that allows them to transfer what they have learned. A variety of research-based instructional strategies can be used to support the learning needs of students with LD. The Access Center’s Strategies to Provide Access to the General Education Curriculum provides an in-depth look at research-based strategies that can help support students with disabilities. These strategies, along with those highlighted in this brief, can help foster success for students with disabilities in an inquiry-based classroom.

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For additional information on this or other topics, please contact The Access Center at accesscenter@air.org.

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1000 Thomas Jefferson St. NW, Washington, DC 20007
Ph: 202-403-5000 TTY: 877-334-3499 Fax: 202-403-5001
e-mail: accesscenter@air.org website: www.k8accesscenter.org

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