Science

13

Contents of this chapter

"The [scientific] 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'[1] through inquiry."

– The Access Center and American Institutes for Research in "Science Inquiry: The Link to Accessing the General Education Curriculum"

Inquiry is an important component of science education and an ideal place to begin differentiating instruction. Inquiry-based learning is a process where students formulate questions, investigate widely and then build new understandings, meanings and knowledge. This knowledge may be used to answer a question, to develop a solution or to support a position or point of view. The knowledge is usually presented to others and may result in some sort of action. Although inquiry-based learning takes time and commitment to implement, the benefits are obvious—students learn to question, explore, research, test, analyze, compare and pose ideas. "Opportunities to think and behave as scientists provide relevance and credibility to student 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" (The Access Center and American Institutes for Research, p. 7).

Effective inquiry-based instruction naturally builds in elements of differentiation. You can further emphasize differentiated instruction by purposefully planning ways to:

- offer learning experiences that vary in complexity, open-endedness and structure
- deal with authentic, real-life problems within the context of the curriculum and community
- incorporate more student choice, including opportunities for students to generate and pursue their own science-related questions
- support students in multiple ways and scaffold instruction as they build understandings of science
- model behaviours, language and multiple processes for gathering and presenting information
- encourage meaningful personal connections and applications of scientific concepts
- make student understandings of scientific concepts visible at each phase of the inquiry process
- provide constructive and instructive feedback to students at each phase of the inquiry process.

1. Reprinted with permission from *National Science Education Standards* (p. 23), 1996, by the National Academy of Sciences, courtesy of the National Academies Press, Washington, DC.

This chapter provides suggestions for differentiating instruction in science within a scientific inquiry model. There are many types of inquiry and the sample process discussed in this chapter will focus on a research inquiry. For more information and strategies related to inquiry, see *Focus on Inquiry* (Alberta Learning 2004). available at http://education.alberta.ca/media/313361/focusoniquiry.pdf.

Plan for differentiated inquiry

Planning for inquiry-based science instruction begins with an understanding of relevant outcomes and the stages of inquiry. Most inquiry models include the following stages.

1. Planning.
2. Retrieving.
3. Creating and Sharing.
4. Evaluating.

These stages need not be followed in a lock-step sequence. Some students may need opportunities to approach inquiry from the middle or even end points within the process. Students also should be taught to go backwards or forwards in the process and to revisit some phases more than once.

An inquiry model outlines the skills and strategies that need to be taught explicitly in each phase of the process. Referring to the model frequently and consistently during the planning of inquiry-based learning activities keeps instructional concerns in the forefront as you plan learning activities and create instructional materials. Consider the following strategies to help you plan effective, differentiated inquiry activities.

Know your students

Use learner profiles, pre-assessments, observation, discussion and other strategies to learn about students' individual strengths, interests, experiences and background knowledge. This information is vital to choosing relevant topics and to making effective decisions about instruction and assessment. For more information about learner profiles, see *Chapter 3: Developing Learner Profiles*.

Identify topics

It is important to select a topic or theme that is worthy of the time and effort involved and that will be interesting to students for more than a short-term period. Early selection of a theme and inquiry activity will give you the time to build student background knowledge, to develop the inquiry skills and strategies that students will need, and to gather the required resources. The most successful curriculum inquiry projects emerge from topics that are of personal interest to the students (Wiggins and McTighe 1998). In a teacher-directed inquiry project, students need to have a choice of topics about which they truly wonder and care, and there needs to be an identifiable time when students work on their inquiries.

In student-directed inquiry projects, you may provide curriculum-related themes and allow students to generate their own topic questions. It is important to ensure that appropriate resources are available for the topics students will be investigating.

Separate content from process

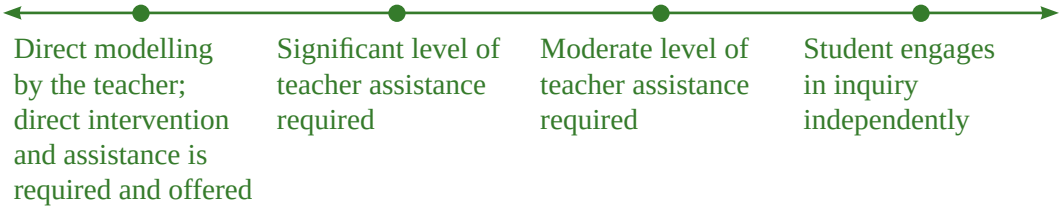
Separating *what* students are learning from *how* they are learning can provide more opportunities to meet a greater range of differing student needs. Using this approach, you could have all students working with common content that is described in the program of studies. However, students will have different levels of engagement with that content, as well as different process skills. Learners will, therefore, differ in the depth, scope, detail and sophistication of the processes and products that stem from a given inquiry. By being mindful of the possibilities for separating content and process, there is a greater dimension of flexibility for differentiation.

Consider grouping options

There are many possible groupings for inquiry activities. Will students work individually, in pairs, small groups or as a whole class? If working in pairs or in small groups, how might student strengths and needs be balanced by the composition of the groupings? In upper elementary grades, consider how reading ability can affect this decision. Students who require more assistance could be partnered with students who require less support. Individual learner profiles and class profiles can be helpful in planning appropriate groupings to provide optimal levels of support.

Identify scaffolding opportunities

All learners of science need opportunities for appropriate challenge, growth and success. Some students will require concrete and tangible examples that provide clear, guided support. Others can develop and apply skills in increasingly independent, abstract and complex contexts. It may be helpful to consider student needs along a continuum of support through to independence. That is, students will vary in the degree of teacher support that will be required in order for them to successfully engage in scientific inquiry. Aim to provide students with multiple contexts, ranging from independent experiences to guided inquiries to group or partner-supported inquiry. Individual students also may require differing levels of assistance at the various stages of the inquiry process.



Assess student learning

An important way to differentiate instruction is to consider student needs and talents as learners of science before beginning the first phase of an inquiry-based project. Asking students to complete a simple inventory can help identify where and how to support them as they engage in scientific inquiry. Such pre-assessments also can be a valuable addition to learner profiles, and aid in planning other aspects of differentiation, such as activities differentiated by student interests or learning preferences. A sample inventory is included as *Tool 1: What Kind of Science Learner am I?* at the end of this chapter.

As you progress through the inquiry, contine to assess learning on an ongoing basis to help you effectively adjust teaching strategies and levels of support for individual students and student groupings. Assessment *for* learning may be accomplished individually, in pairs or small groups, by peers or as a whole class activity. It is important to use assessment tasks to make student understanding explicit and to provide feedback about both the inquiry itself and related skills such as teamwork. This feedback should describe and support progress and not necessarily be recorded as part of students' final evaluations.

Concept attainment

One useful assessment *for* learning strategy is concept attainment. This strategy is particularly helpful toward the end of the retrieving and processing phase to identify any misconceptions regarding a particular science concept under investigation. Concept attainment may be done with individual students, small groups or with the whole class, depending on learning needs. The basic steps involved are listed below and can be adjusted based on student developmental levels.

1. Set up a section of the board or a piece of paper with two columns: one labelled "Yes" and the other labelled "No."

2. Use individual strips of paper to record (a) the attributes of the science concept, (b) exemplars that illustrate the science concept, and (c) non-exemplars that help to illustrate what is *not* associated with the science concept. Note that student work on the inquiry to this point may be a source for non-exemplars if the student is misinterpreting information. However, this kind of feedback needs to be given with sensitivity; e.g., individually rather than in front of the group.

3. Without identifying the specific science concept to students, share the strips of paper with students, one strip at a time. Ask students to decide if the given strip belongs on the "Yes" side or the "No" side of the chart. Students should recognize the science concept as the activity unfolds; if not, this is an indicator that additional instruction may be required.

4. Lead and encourage discussion throughout the activity about why students are making certain choices. The goal is that, toward the end of the activity, students will be able to identify the science concept and to more solidly delineate the critical attributes of that concept.

Assessment and evaluation *of* learning is not required at every phase of an inquiry, nor even for every inquiry. Students need supportive opportunities throughout an inquiry to work toward independence without the pressure of evaluative scoring. When final evaluations are appropriate, watch for opportunities to differentiate the assessment process; e.g., How will students demonstrate and share their learning? What are the different possibilities for students to best demonstrate their learning while still allowing you to assess the same curricular outcomes for the class as a whole? Science assessment often relies on writing, which can create challenges for some students. Providing opportunities for students to communicate learning in a variety of ways, including using drawing and presentations, ensures that all students can accurately demonstrate their learning.

For more information, see *Chapter 4: Differentiated Assessment*.

Inquiry and differentiated learning experiences

Inquiries can be differentiated through pacing, complexity and degree of support; through providing a variety and choice of activities; and through actively engaging students at all phases of the inquiry. Ongoing reflection and dialogue with students are critical aspects of the entire inquiry process, as plans and questions should be revisited and, if necessary, revised as the process unfolds. Student understanding of inquiry is enhanced when you explicitly teach and frequently refer to the inquiry model you are using. Post the model in your classroom and the school library so students may reference it at any time.

The following list provides an overview of sample approaches and strategies for differentiated inquiry-based learning experiences. Although the strategies are organized by phases of the inquiry process, many of these strategies can be adapted and used at multiple phases. For more information on differentiating learning experiences through scaffolding, flexible grouping, student choice and other strategies, see *Chapter 5: Differentiated Learning Experiences*.

1 Planning phase

In this phase, students:

- identify a topic for inquiry
- identify possible information sources
- identify audience and presentation format
- establish evaluation criteria
- outline a plan for inquiry.

Consider the following sample strategies and approaches to differentiate instruction during the planning phase of inquiry.

Make connections

- Use visual, audio, narrative and musical examples to introduce a topic, inquiry question or investigation, draw out affective responses, and encourage students to make comparisons and draw inferences based on their prior knowledge and understandings.
- Connect personal life experiences to abstract ideas and concepts. Model using personal examples and insights related to a scientific inquiry or investigation.
- Encourage students to make predictions and hypotheses as they begin their inquiry. Ask them to reflect explicitly on prior knowledge and make their own connections to new science concepts and topics.
- Teach students how to use graphic organizers to describe their prior knowledge and organize their thinking and learning. For example, use a "K-W-L chart" to encourage students to track and reflect on their learning from the beginning of a topic of study to its completion. The "K-W-L chart" can help to establish direction for the inquiry and promote reflection at the end of the inquiry.

K	W	L
What I Know (How do I know it?)	What I Want to Know (Why do I want to know?)	What I Learned (How can I apply what I learned?)

Use flexible groupings

- Have students structure their plan for inquiry individually, in partners, in small groups or as a whole class.
- Have students find a partner who is interested in the same question or in using the same source of information.
- Invite students to "think-pair-share", by reflecting on the question, sharing their response with a partner and then contributing their ideas to a class discussion.
- Invite students to generate their own questions that will guide further research and exploration. Compare questions and use as the basis for forming research groups.

Use scaffolding strategies

- Use demonstrations and modelling with "think-alouds" to walk through steps in applying a skill.
- Provide multiple opportunities to practise skills and apply processes with support. Include guided practice in which you work through examples with students.

- Use inductive problem-solving activities to introduce and model the inquiry process. Provide students with a problem or issue and invite them to ask questions that can be answered with only "yes-no" responses to obtain more information. Emphasize skills of applying logic to information, processing responses and using information gained to lead to new questions. Once students believe they have enough information, they can present a hypothesis.

Provide opportunities for student choice

- Develop a list of inquiry questions or topics related to a concept from which students can select one that most interests them.
- Ensure that students have the opportunity, at one or more points in the year, to generate their own questions for inquiry. Some students may require assistance in the formation and refining of questions, but it is important that they are able to pursue topics that are of interest and are meaningful to them.

2 Retrieving and processing phase

In this phase, students:

- develop an information retrieval plan
- locate, collect and evaluate information resources
- establish a focus for inquiry
- evaluate, choose and record pertinent information
- make connections and inferences
- review and revise the plan for inquiry one or more times as they work through these steps.

Retrieving and processing can be bundled together, as the process of scientific inquiry often requires an interplay between them. Movement between them also will depend on personal preferences, student needs and teaching styles.

Consider the following sample strategies and approaches to differentiate instruction during the retrieving and processing phase of inquiry.

Vary the context, tasks and sources

- Have students complete the same task with different information sources.
- Have students use the same information source to complete different tasks or apply different processes.
- Have students use the same information source and process to complete different projects or products.

Use flexible groupings

- Provide different contexts in which students respond to questions or explore information, including whole class, small group and partner discussions, and individual student reflection.

- Have individual students pool research and information from different sources to share with the class. For example, provide each student with recipe cards, post-it notes or strips of paper. Have students record one fact per card. Post the recorded facts on a bulletin board or other common space so that other students can access their peers' research. Monitor the postings for accuracy, and discuss any misconceptions or inaccuracies with students so that they can be corrected together.
- Have students explore sources of information using "carousel" or "gallery walk" strategies. Organize different sources in stations or displays around the classroom and invite students to visit different stations to select, summarize, organize and analyze content.
- Establish learning centres using classroom areas, pizza box or other containers to hold different types of sources of information.
- Provide opportunities for students to chunk content, share understandings and apply knowledge and understandings by teaching others. For example, use a "cooperative learning jigsaw strategy" to divide responsibilities among groups of students and provide them with the opportunity to teach others what they have learned. Expert groups can be based on differing predictions or hypotheses, sources of information or experiments.
- Vary questioning strategies to provide opportunities for students to contribute meaningfully to discussions.

Provide information in multiple formats

- Provide multiple examples related to the topic and concepts.
- Present concepts through hands-on or concrete materials, experimentation, models and demonstrations.
- Provide visual supports, including videos, images, highlighted text and photocopies of key words and notes, to enhance understanding of the concepts under investigation and the inquiry process itself.
- Whenever possible, provide a variety of parallel texts on the same topic with a range of reading levels.
- Ask students to think of and share different ways they can represent information, terms and concepts. Encourage students to develop mental, symbolic and nonlinguistic representations of textual information.
- Read textual information out loud as students listen with their eyes closed, encouraging students to ask questions as they listen. Have students create a mental picture of what they 'see in their minds' and then share, categorize and prioritize their insights by using a graphic organizer.

Encourage active engagement and critical thinking

- Encourage students to use multiple sources of information to answer questions. Teach students to consider and evaluate multiple perspectives, and to explore consistencies and inconsistencies between sources.

- Encourage students to compare and contrast different data sets or information from different sources. Have students use an "interactive notebook format" or "split page organizer" to record information and reflect on similarities and differences. An interactive notebook or split page organizer divides a notebook page into two columns, and asks students to record facts and information on the right column and personal insights, questions and reflections on the left side.
- Provide a research retrieval chart that requires students to identify consistent and inconsistent information between different sources and compare with experimental data or personal hypotheses or predictions.

Help students organize, analyze and manage information

- Provide key information or use key questions as an advance organizer to help students organize and make sense of new content.
- Teach students to select the graphic organizer that best supports their learning needs and the specific task. Invite students to create their own graphic organizer, specific to an identified purpose.
- Chunk text and tasks into smaller, manageable sections.
- Colour-code handouts and text or use sticky notes to mark important sections of text.
- Pre-teach key vocabulary.
- Watch for students who are feeling frustrated or overwhelmed by finding too many or too few information sources. Teach students that these feelings are ones that many inquirers experience, and provide skills and strategies for selecting relevant information and for modifying inquiries when necessary.
- Teach students how to compare, contrast and synthesize data to choose pertinent information from resources.

3 Creating and sharing phase

In this phase, students

- organize information
- think about the audience
- create a product
- revise and edit
- present new understandings
- demonstrate appropriate audience behaviour.

Consider the following sample strategies and approaches to differentiate instruction during the creating and sharing phase of inquiry.

Encourage new interpretations

- Provide opportunities for students to organize and share their data in accordance with their own background knowledge, experiences and learning preferences.

- Use a "concept formation" strategy. Concept formation employs divergent thinking—every answer will be considered to be correct as long as students can articulate a logical and reasonable rationale. In this strategy, students do the following.
    1. Record facts on strips of paper. These facts must stem from a reliable source and should be monitored for accuracy.
    2. Spread out the information on a flat surface.
    3. Group the facts by physically moving the strips of paper into clusters and labelling each cluster. Students should be able to describe a rationale for each grouping, including only the critical attributes that define each category.

  When students are finished, review the labelled clusters, encouraging them to consider areas where additional research may be required. The process of organizing and expanding on the information base may go back and forth several times before a complete data set is created.

Provide variety and choice

- Provide choices for students to demonstrate skills with the same content.
- Invite students to demonstrate skills using different content, selected by interest, readability or differentiated topics.
- Offer students choice in product development and assessment; for example, provide the option to use choice boards, cubes or matrixes to create products that demonstrate knowledge and understandings.
- Provide options for students to communicate their learning through illustrated and/or textual storyboards, illustrated and/or text-based time lines, maps (bird's eye views), labelled diagrams, posters, tables, picture glossaries, diagrams to scale, analytic or cutaway diagrams, comparative diagrams, illustrated cross sections, flowcharts to flow diagrams (to illustrate change, growth or development, cause and effect, chain of sequence), tree diagrams, webs, concept maps, graphs (bar, column, line, pie), two- and three- dimensional models, and illustrated and/or textual tables.

Promote success

- Help students keep their creation to a manageable scope.
- Provide supports and scaffolds within the structure of a project to encourage students to demonstrate their learning on different levels.
- Provide agendas, menus or task lists to guide students through assignments or projects, especially when the task requires students to work with a learning preference that they are not the most proficient in.
- Set up learning centres with different projects as their focus. Work with groups of students to map their use and complete the tasks within all or some of the centres.
- Break long-term assignments or projects into smaller steps, with clear due dates and frequent feedback.

- Provide checklists to help students manage multi-step tasks or post daily assignment requirements.
- Provide instruction on when and how to use various formats (e.g., labelled diagrams, posters, tables, picture glossaries, diagrams to scale), and make samples or models available to students to encourage them to correctly use different modes for communicating their learning.
- Make sample completed projects available so students can plan projects and products with the end in mind.

Provide opportunities to share results

- Provide bulletin board or other display space to students on a regular basis.
- Have students share their inquiry work with others through a poster presentation, a format similar to that used at conferences where scientific research is shared with the larger professional science community.
- Set up a trade show where desks or tables are organized into a horseshoe shape and work is displayed.
- Invite other classes of students, parents or members of the community to the science classroom to view and hear about student research and inquiry products.
- Explicitly teach audience appreciation skills and strategies.

4 Evaluating phase

In this phase, students:

- evaluate the product
- evaluate the inquiry process and inquiry plan
- review and revise personal inquiry model
- transfer learning to new situations, including those beyond school
- identify new questions and applications for their learning.

Consider the following sample strategies and approaches to differentiate instruction during the evaluating phase of inquiry.

Create opportunities for self-assessment

- Include frequent opportunities for ongoing and formative assessment, such as rating scales and self-reflective writing assignments. In addition to more formal approaches, consider simple strategies such as asking students to hold up a number of fingers to self-assess understanding, or to use thumbs up or down to indicate agreement or disagreement.
- Provide regular opportunities for students to use and be involved in creating rating scales, criteria and rubrics.
- Use index cards as exit cards to have students self-assess and reflect on their application of a skill or process throughout the inquiry process by writing down an answer to a question or prompt such as “Name one thing you learned today about ....”
- Use the accumulated observations to assist in evaluating the process as a whole.

Encourage personal reflection

- Encourage students to reflect on and discuss questions such as:
  - What went well in each phase of this inquiry?
  - What might I change to make my work stronger and to increase my learning and skill level?
  - What have I learned in this inquiry?
  - What was the highlight of this assignment? Why?
  - What did I learn that I can transfer to other tasks in and out of school?
- Provide an opportunity for students to complete and reflect on their "K-W-L charts."
- Encourage students to read their personal journals and reflect on them.
- Have students write, draw, present or represent syntheses of their activities.

Tool 1: What Kind of Science Learner Am I?

1. On a scale of 1 to 10 (one being least and 10 being most), I enjoy learning about science.

   1 2 3 4 5 6 7 8 9 10

2. On a scale of 1 to 10 (one being least and 10 being most), I do well in science.

   1 2 3 4 5 6 7 8 9 10

3. When doing science, I like to work (check all that apply to you):
   - ❑ alone
   - ❑ with a partner
   - ❑ in a small group
   - ❑ as a whole class

4. In learning about science, I like to (check all that apply to you):
   - ❑ read
   - ❑ watch demonstrations of inquiries
   - ❑ carry out inquiries that have been developed by others
   - ❑ design and carry out my own inquiries
   - ❑ other _____

5. I prefer to show my learning in science by (check all that apply to you):
   - ❑ writing
   - ❑ drawing
   - ❑ charting
   - ❑ sharing orally
   - ❑ using models
   - ❑ using a computer (e.g., PowerPoint presentations)
   - ❑ other _____

6. Areas that I do well in science include: _____

   _____

7. Areas that I struggle with in science include: _____

   _____

   _____

8. An area that I would like to improve on in science is: _____

   _____

   _____