

the teacher. A month into the school year, the teacher may offer students the opportunity to rearrange the room according to their own design. This makes the room truly “their room” and adds a degree of student ownership to the room.

## Design Your Inquiry-Centered Classroom

We now know how inquiry-centered environments are different from teacher-centered environments. You can demonstrate that understanding by designing an inquiry-centered classroom of your own. On a separate sheet of paper, design a room for the number of students in your present classroom. Place the teacher desk, the student desks, and learning centers in any way that complements the size and shape of your present classroom. Use several of the 12 characteristics listed above as a guide. When completed, share your design with another person in your class or study group. Discuss the similarities and differences in your designs.

We will now transition into the second aspect of our examination—the behavior of students in an inquiry-centered classroom.

## Students in an Inquiry-Centered Classroom

In an inquiry-centered classroom, students demonstrate different behaviors and habits of mind from their counterparts in non-inquiry classrooms. In an inquiry-centered science classroom, students do the following:

- Enjoy posing questions and demonstrate a desire to learn
- Show an interest and imagination in science by acting as researchers/investigators and viewing themselves as scientists
- Engage in diligent investigations from their self-generated questions
- Reflect on and take responsibility for their individual learning
- Persist in asking questions to clarify and confirm the accuracy of their understandings
- Work respectfully and communicate in collaborative groups
- Utilize higher-order thinking skills to solve problems and make judgments about their work
- Consider skepticism and alternative models or points of view
- Use claims and unbiased evidence to form explanations and arguments
- Connect new knowledge to prior understandings
- Make decisions as to how to communicate their work
- Demonstrate their science understandings and abilities in a variety of forms
- Act as “reflective friends” through peer evaluation to seek other opinions and assess the strengths and limitations of their work
- Demonstrate confidence in their learning, take risks, and persevere

Since students are at the center of inquiry learning, it is appropriate to continue our examination with student behaviors that characterize inquiry. When watching students doing inquiry, we generally observe the following:

- Students acting as researchers
- Students working in groups

- Students using critical-thinking skills
- Students showing an interest in science

The next sections will highlight each of the four observations.

### **Students Acting as Researchers**

Curiosity is the heart of inquiry. Curiosity pumps questions throughout the learner. When students act as researchers, they take on a new role in an inquiry-centered classroom. Action research leads students to use integrated process skills such as identifying variables, clarifying assumptions, writing hypotheses, designing and carrying out investigations, constructing data tables and graphs, analyzing relationships between variables, finding patterns, and justifying and defending their evidence and claims. While acting as researchers and using the integrated process skills previously mentioned, students incorporate the eight practices from the NGSS into their investigations:

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information (NRC, 2013)

Having students act as researchers is a challenging endeavor for both students and teachers. For students to take on new roles, teachers must assume new roles as well. In a culture of inquiry, teachers must believe that students have the abilities and interest to carry out their own investigations and generate their particular, and sometimes peculiar, explanations. When students act as researchers, they commence taking responsibility for their own learning. Most students prefer to answer their own questions and solve their own problems rather than respond to someone else's. As researchers, students can make decisions about their own work, such as how they will collect and organize data and how they will communicate their claims and evidence to the rest of the class. By planning and designing their inquiries, students begin to use higher-level critical-thinking skills, such as analyzing and evaluating, to guide the design and course of their investigations. Teachers will begin to find that they need to provide fewer answers and more support to students. A teacher's support may include (a) guiding the students to a location to search the Internet for a particular topic, (b) suggesting that they consult an expert on the topic, or (c) recommending primary sources for the students to review.

### **Students Working in Groups**

In the real world, scientists and engineers work predominantly in groups and less often as individual, isolated researchers. Therefore, the collaborative nature of integrating science, technology, engineering, and mathematics (STEM) should be mirrored and

strongly reinforced by recurrent group work in elementary and middle school classrooms, giving students ample opportunities to share the responsibility for learning with each other. Group work can allow students to share and challenge ideas and distribute the work in an equitable fashion. In group settings, students learn to negotiate and construct knowledge together while building positive peer relationships. Group work also allows students to build self-confidence while working collaboratively to complete a common goal. Having students work in groups, however, always requires consideration of gender and cultural equity as well as the interests, needs, and abilities of the group members.

In both elementary and middle school settings, group work often becomes louder than seat-time work. Because students are expected to communicate and move about the room while working in groups, effective classroom management techniques become essential. Students need and want rules of conduct to be established. They want to know the expectations of classroom behavior. Problems often occur in inquiry classrooms when the teacher fails to effectively communicate the expected behavior for group work. The teacher can enhance expectations and rules for appropriate behavior by having students participate in deciding what rules need to be enforced while doing a scientific investigation. The students can agree to the rules, which can then be posted in the classroom. Classes can consider adopting rules of conduct by citing the positive behaviors that are expected (starting with the word *Do*) rather than rules written in a negative tone (starting with the word *Don't*).

### **Students Using Critical-Thinking Skills**

In a community of inquirers, using exploration and discourse strategies stimulates students to think critically about the data and evidence accumulated during their inquiries. This motivates students to analyze and synthesize the data and to make judgments and evaluations about the results and conclusions. These types of higher-thinking skills are far superior in developing scientific literacy to the skills involved in answering the kinds of questions repeatedly posed to students in classrooms where recall and memorization of science fact are valued. In contrast, as students experience inquiry investigations, they use critical-thinking skills that cause them to reflect on their work and pose logical arguments to defend their conclusions.

In *Taking Science to School* (NRC, 2007), thinking skills in inquiry in Grades K–2 involve students generating questions and making sense of their ideas. In Grades 3–5, students are beginning to make the transition into higher-level concrete operations and are more likely to understand the relationships between their prior knowledge and their new experiences. In middle school, students in Grades 6–8 are better equipped to see cause-and-effect relationships, formulate hypotheses, interpret data and draw conclusions, evaluate relationships between variables, and use two- and three-dimensional models to explain their conclusions. Throughout the middle school years, many students begin to make the transition from concrete operations to formal levels of operations and thinking more abstractly.

### **Students Showing Interest in Science**

“Why do we have to learn this stuff anyway?” one eighth-grade girl asked her teacher. Have you ever been asked that question? It seems that every experienced teacher has been asked it a hundred times in his career. From the point of view of the student, what does the question mean? Does it mean she doesn’t like science? Does it mean she doesn’t

like this particular lesson? Or does it mean she doesn't understand what she is expected to do? All we know at this point is that the student might not see the relevance of the content she is expected to learn.

Posing problems of importance and relevance to students is an integral aspect of inquiry and constructivist teaching (Brooks & Brooks, 1999). That does not mean that in inquiry classrooms, the students unilaterally decide what and when they want to learn. Nor does it mean that teachers must wait until the students want to learn about Newtonian physics before the subject can be presented. It does mean, however, that in inquiry classrooms, the teacher mediates relevance by engaging students in meaningful problem-solving investigations. According to Brooks and Brooks (1999), "The inquiring teacher mediates the classroom environment in accordance with both the primary concept she has chosen for the class's inquiry and her growing understanding of students' emerging interests and cognitive abilities within the concept" (p. 38). Making learning meaningful is another central theme in a culture of inquiry. Brooks and Brooks go on to say,

It's unfortunate that much of what we seek to teach our students is of little interest to them at that particular point in their lives. Curriculums and syllabi developed by publishers or state-level specialists are based on adult notions of what students of different ages need to know. Even when the topics are of interest to students, the recommended methodologies for teaching the topics sometimes are not. Little wonder, then, why more of those magnificent moments don't occur. (p. 106)

In inquiry-centered classrooms, students are engaged in investigations that interest them through prompting and mediation from the teacher. As a result, students demonstrate open-mindedness and, furthermore, gain an appreciation for science. Acting as researchers promotes an interest in science as well as a positive attitude that encourages students to pursue more rigorous science courses in the years ahead.

In the 1990s, NETWORK, Inc. (Andover, Massachusetts) received a grant from the National Science Foundation to support inquiry-based learning. The project, titled Vermont Elementary Science Project (VESP), was located at Trinity College in Burlington, Vermont. Participants in VESP discussed the actions of students engaged in inquiry science. As a result of that discussion, they created the *On the Run Reference Guide to the Nature of Elementary Science for the Student*. Although the document was created almost 25 year ago, it is still as significant today as it was when it was written. According to VESP,<sup>1</sup>

the intent is not to use the guide as a checklist, but as a statement of what we value in the area of science processes, science dispositions, and science development. We urge you to capture evidence of your own students engaging in these indicators.

VESP suggests that "when students are doing inquiry-based science, an observer will see" the following:

*Students View Themselves as Scientists in the Process of Learning*

1. They look forward to doing science.
2. They demonstrate a desire to know more.
3. They seek to collaborate and work in cooperative groups with their peers.

4. They are confident in doing science; they demonstrate a willingness to modify ideas, take risks, and display healthy skepticism.
5. They respect individuals and differing points of view.

*Students Accept an “Invitation to Learn” and Readily Engage in the Exploration Process*

1. Students exhibit curiosity and ponder observations.
2. They take the opportunity and time to try out and persevere with their own ideas.

*Students Plan and Carry Out Investigations*

1. Students design a fair test as a way to try out their ideas, not expecting to be told what to do.
2. They plan ways to verify, extend, or discard ideas.
3. They carry out investigations by handling materials with care, observing, measuring, and recording data.

*Students Communicate Using a Variety of Methods*

1. Children express ideas in a variety of ways: journals, reporting out, drawing, graphing, charting, etc.
2. They listen, speak, and write about science with parents, teachers, and peers.
3. They use the language of the processes of science.
4. They communicate their level of understanding of concepts that they have developed to date.

*Students Propose Explanations and Solutions and Build a Store of Concepts*

1. Students offer explanations from a “store” of previous experience and from knowledge gained as a result of ongoing investigation.
2. They use investigations to satisfy their own questions.
3. They sort out information and decide what is important (what does and doesn’t work).
4. They are willing to revise explanations and consider new ideas as they gain new knowledge (build understanding).

*Students Raise Questions*

1. Students ask questions (verbally or through actions).
2. They use questions to lead them to investigations that generate or refine further questions and ideas.
3. Students value and enjoy asking questions as an important part of science.

*Students Use Observations*

1. Students observe carefully, as opposed to just looking.
2. They see details, seek patterns, and detect sequences and events; they notice change, similarities, and differences.
3. They make connections to previously held ideas.

*Students Critique Their Science Practices*

1. They create and use indicators to assess their own work.
2. They report and celebrate their strengths and identify what they'd like to improve upon.
3. They reflect with adults and their peers.

So far, we have seen the importance of the classroom environment and have reviewed student attitudes and behaviors in a student-centered inquiry classroom. We will now take a look at the third and final aspect of our examination: the role of teachers in an inquiry-centered classroom.

## **Teachers in an Inquiry-Centered Classroom**

The teacher's competency is paramount in inquiry-centered classrooms. It sets the stage for teaching and learning. When observing inquiry-based teachers, we often see a different style of presentation, organization, questioning skills, and even body language from what is seen in traditional settings. The following is a laundry list that often accompanies good teaching as well as inquiry-based learning. In inquiry classrooms, we often see teachers

1. using *A Framework for K–12 Science Education* and the *Next Generation Science Standards* (as well as statewide standards) to guide their long-range instructional plans;
2. fostering a classroom culture that encourages positive scientific attitudes and habits of mind;
3. planning lessons utilizing the 5E Learning Cycle;
4. being focused yet flexible by having preplanned lessons and questions while mediating the lesson to follow the direction of the students' questions;
5. assessing prior knowledge before starting a lesson or unit of study and using students' prior knowledge as a basis for introducing new concepts and adjusting instruction accordingly;
6. listening to students' responses and becoming aware of their misconceptions;
7. making learning meaningful by exploring student interests, taking those interests into account, and basing lessons on students' prior suppositions;
8. using investigations to anchor new information to previous knowledge;