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INTRODUCTION
LEADING CHANGE

Principals are pivotal to setting a positive tone and establishing a climate for sustainable increases in achievement. By *climate*, we mean how people feel about their school and the combination of stakeholders' shared values, attitudes, and beliefs. Stakeholders include students, teachers, administrators, parents, bus drivers, office personnel, custodians, cafeteria workers, and other people who play an instrumental role in the culture of the school. When you lead, you turn beliefs about science education into actions.

A principal who values a strong, comprehensive science program will establish the right climate by instilling pride in science teaching among his or her staff, modeling good science teaching and organizing his or her school in order to promote it, acknowledging success when it occurs, and protecting the values and beliefs that promote science teaching from the intrusion of state and federal mandates. To instill pride, a principal might say to his or her teachers, "We are on our way to becoming one of the premier schools in the state for science education." To model science teaching that works, a principal might ask someone to demonstrate a science lesson and host a conversation about it afterward. To acknowledge success, a principal could publicly recognize those teachers who entered the most students in the state science fair. Finally, to protect science teaching from intrusion, principals can jealously guard time allotted in teachers' schedules for that purpose.

Beginning the Process

At times, it can be quite intimidating to anticipate all that is needed to lead a school toward an improved focus on an interdisciplinary science program. To prepare the way, you can take four actions.

1. Prior to any substantial change initiative, assess your successes in curriculum, instruction, and student learning.

2. Engage your staff in a discussion on the many things they are doing already to foster inquiry-based thinking, incorporate STEM (science, technology, engineering, and mathematics), and promote hands-on learning.
3. Acknowledge the fear or discomfort learners may have with science. Determine through conversations what they know about experimental design or key scientific concepts.
4. Most importantly, assess stakeholders' desire to make science a shared value for the entire school community.

Holistic improvement is within reach once you determine that your staff members are ready and willing to invest their time and energy to work collaboratively in this endeavor. But real reform requires developing a vision, articulating a plan for change, and getting behind it. As the instructional and managerial leader of your school, you have the opportunity to influence many decisions that have a direct impact on science teaching. Specifically, you can do the following:

- Keep science interests and experiences in mind when hiring staff.
- Include current staff at some stage of the hiring process.
- Support your staff with the latest technology.
- Ensure that time is allocated in faculty meetings for learning more about science inquiry.
- Conduct formal and informal classroom visits during science instruction.
- Encourage thematic team planning centered on science concepts.
- Protect teacher setup time so that materials management is reasonable.
- Host student assemblies that honor student efforts in science.
- Provide relevant and meaningful professional development in K–8 science instruction.
- Distribute articles on science teaching prior to faculty meetings, as well as for summer reading.
- Brainstorm with teachers on a routine basis. Continuously ask them for their input and ideas on how to improve the overall science program.
- Include science items in staff newsletters, emails, and other correspondence.
- Share what teachers are doing through community newsletters and social media (blogs, Facebook, and Twitter, for example).
- Establish a science focus on the school's website.

Professional Development and Science Education

To develop a schoolwide passion for science, the entire school community must acknowledge the need to focus on science. In the 1950s, the launching of *Sputnik* sparked a national interest in science instruction. Since then, global competition and the emphasis on STEM as a pathway to greater societal sustainability have triggered a renewed sense of urgency in science education. As principals establish their school's needs and identify goals, they can lead their staff through a variety of initiatives, which we explore in this book, to transform the school into an innovative institution that focuses on quality science instruction.

Young learners have a natural affinity toward science, and science concepts and principles pervade all subjects. Educational leaders, principals, and teachers can invite scientists, engineers, and university professors to speak about career opportunities in the field to drive students' excitement. Students studying science have opportunities to practice problem solving and develop critical-thinking skills. Students use mathematics as they measure phenomena and quantify relationships. Science is the focus for resolving complex societal problems, such as environmental conservation and sustainability. Science involves history and language arts strategies. It provides a venue for creativity, innovation, exploration, and engagement with cutting-edge ideas that foster a love of learning. Asking questions, debating, analyzing data, defending ideas, and compromising—these are all part of scientific inquiry. Science is also fun and exciting and prepares students with 21st century skills that are essential for success in a constantly evolving global society. These essential elements of scientific thought and problem solving are found throughout all curricular areas.

About This Book

This second edition of *What Principals Need to Know About Teaching and Learning Science* addresses the essential elements of exemplary science programs while providing practical strategies for increasing science achievement in K–8. This book has been designed as a user-friendly resource to which principals can refer on a continuing basis to improve science instruction in collaboration with their staff. In addition to a comprehensive discussion of the important issues, it includes:

- Reproducible forms, checklists, and other materials to use in evaluating your school's science program and collaborating with all pertinent stakeholders (teachers, parents, and students)
- Lists of questions to consider as you develop a plan to improve instruction and increase science achievement

We've opened *What Principals Need to Know About Teaching and Learning Science* with recommendations on leading change to create a school climate that supports effective science instruction. In chapters 1 and 2, we discuss science instructional materials and science curricula. Chapter 3 offers a self-assessment survey of your science program. Data collected from this survey will assist in determining your school's strengths and weaknesses in regard to science instruction. In chapters 4 and 5, we consider inquiry-based learning and the assessment of science learning, as well as the design of science experiments. Finally, in chapter 6, we outline strategies for professional development to improve science teaching and outline guidelines for observing and evaluating science instruction. The appendices will provide you with valuable resources to refine your science programs and provide support to your teachers. Throughout each section of the book, the focus remains on the principal's role in coordinating the successful implementation of an effective science program.

The *What Principals Need to Know About* series is a curricular resource principals can refer to for concise, research-based information on the major subject areas in K–8 instruction. As the instructional leader in your building, you should be knowledgeable about effective pedagogical practices in each content area and be able to provide teachers with sound instructional feedback, suggestions, and support. We hope you will find this guide useful and will add value to it by recording your notes, observations, and additional Internet resources as you work to refine your school's science program.

ONE
SCIENTIFIC INQUIRY

Scientists share a set of attitudes and beliefs about the nature of our world and the means to investigate its secrets. For example, scientists presume that there are persistent patterns in the universe that can be identified through careful observation and systematic study. They also allow for change in scientific ideas and theories as new knowledge is discovered and new patterns are identified. Scientific knowledge is often described using the *best fit theory*, which states that one cohesive theory explains everything that is known about a topic and can be modified as new knowledge is obtained (Lederman & Lederman, 2004). For example, when new discoveries made it impossible to explain the movement of the planets with Earth in the center of the universe, Copernicus postulated that the planets circle the sun rather than the Earth.

According to Norman Lederman (1999), all students should know the following five tenets concerning the nature of science. Scientific knowledge is:

1. Tentative and therefore subject to change
2. Empirically based on or derived from observations of the natural world
3. Subjective and theory laden
4. Contingent on human inference, imagination, and creativity to develop explanations for occurrences
5. Socially and culturally embedded—a natural part of people's thought process

According to the National Science Teachers Association (NSTA, 2000a), "Science is characterized by the systematic gathering of information through various forms of direct and indirect observations and the testing of this information by methods including, but not limited to, experimentation." The NSTA (2007a) further states that "for science to be taught properly and effectively, labs must be an integral part of the science curriculum." In general, it is best for all learners to have multiple opportunities every week to engage in hands-on science activities in a lab situation.

Scientific Methods and Scientific Literacy

The *scientific method* is often referred to as a staple of effective science instruction. People once believed that scientists used just one method—a step-by-step process—for conducting research, and over the years, many students have had to memorize various lists of steps claiming to be *the* scientific method. But in fact, practicing scientists employ a broad spectrum of methods, and "it is only through engagement in the practices that students can recognize how such knowledge comes about and why some parts of scientific theory are more firmly established than others" (National Research Council [NRC], 2012, p. 43).

Figure 1.1 shows the scientific method in its simplified form.

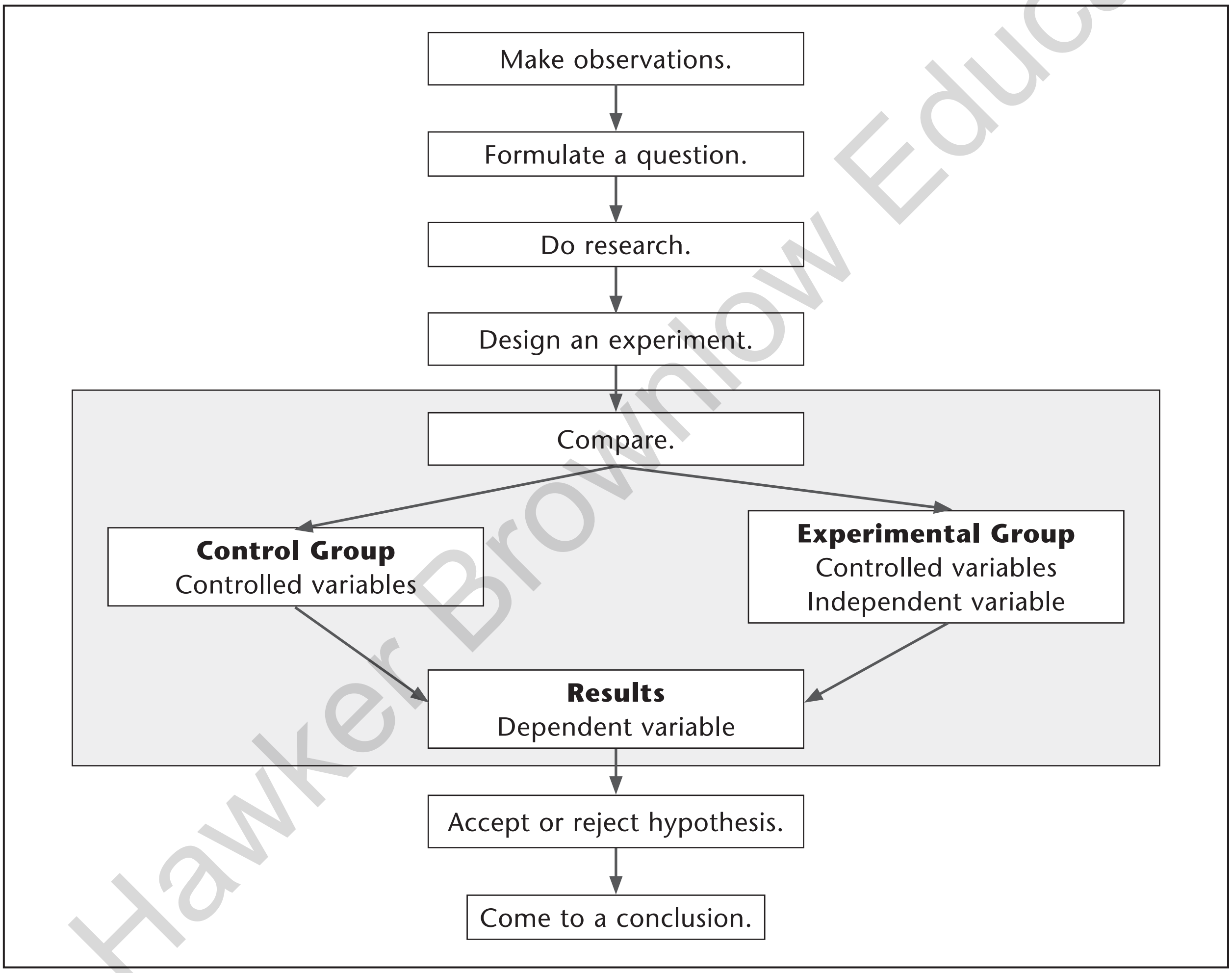

Figure 1.1: A simplified diagram of the process of scientific investigation.

Scientific inquiry is the means by which one attains the deeper understanding of science that we call science literacy. Scientific inquiry allows students to investigate problems, utilizing their knowledge of the scientific method and designing their own experiments and questions to learn about scientific topics. It puts the learner in the shoes of the scientist. According to the NRC (1996), “Lifelong scientific literacy begins with attitudes and values established in the earliest years” (p. 18). At the heart of scientific literacy are the habits of making observations, asking questions, exploring natural phenomena, conducting experiments, finding patterns in data, seeking knowledge, and solving problems. Methods of teaching using inquiry foster scientific curiosity in children.

A central strategy for inquiry is to start with science questions that students generate from their own experiences. In this way, science becomes an active process in which students engage in *hands-on* investigations as well as *minds-on* analyses of observations. Hands-on learning coupled with active inquiry is time consuming and resource intensive, yet it is one of the highest priorities of the greater science education community.

An Example of Scientific Investigation: What Makes Yeast Rise?

A science teacher conducts an experiment to show his classes that yeast will produce gas when mixed with certain solutions but not others. The teacher illustrates this by mixing yeast with apple juice in one flask and with water in another. The teacher then puts a balloon over both flasks, and students watch what happens to each balloon throughout the course of the day.

They notice that the balloon over the apple juice begins to inflate, while the balloon over the water does not. The teacher does this setup with two different classes, placing one class’s flasks on a desk in the back of the room and the other set on the windowsill. By the end of the day, the balloons covering the flasks on the windowsill are significantly more inflated than the ones in the back of the room. This arouses the curiosity of the students, and a flurry of questions follow.

Student 1: Why is the one by the window bigger?

Teacher: Why do you think?

Student 1: Because it is in the sun?

Teacher: That’s possible; are there any other thoughts?

Student 2: Maybe it got hotter by the window, and the higher temperature made the yeast eat the sugar faster.

Teacher: How does eating sugar make the balloon get bigger?

Student 3: The byproduct of the yeast eating the sugar is carbon dioxide. The more sugar the yeast eat, the more carbon dioxide they produce.

Teacher: Good. Those are both great thoughts. How could you test them? I would like everyone to select one of those two hypotheses and design a scientific experiment to test if either or both of those factors affected the results of my demonstration.