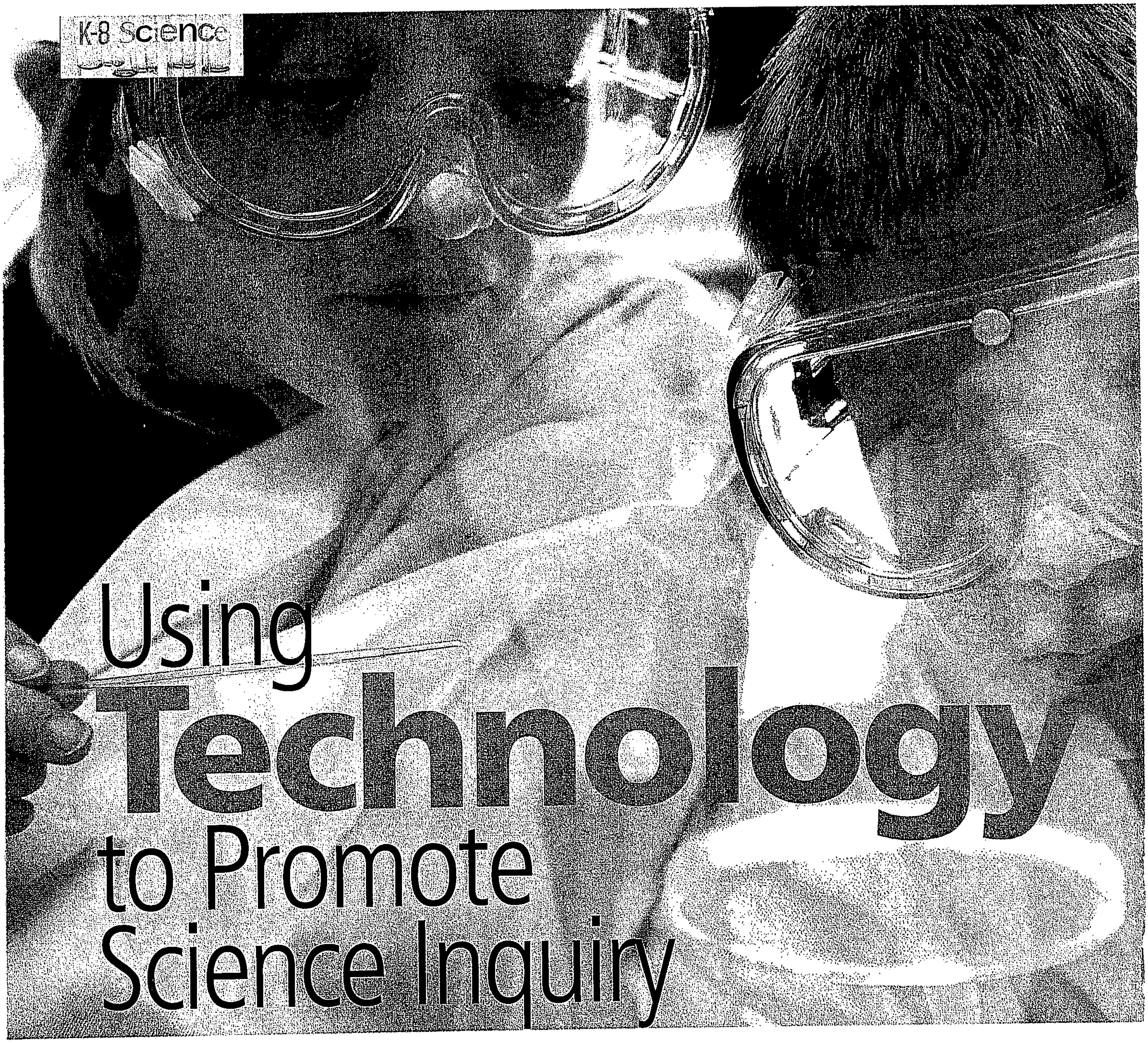

Using Technology to Promote Science Inquiry

Technology provides powerful tools to help teachers lead their students through the inquiry process.

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and Matt Kuhn

This article makes the case for infusing technology into the five stages of the science inquiry process established by the National Science Education Standards—engagement, planning, investigating, analyzing, and communicating.

Professional education organizations in every discipline agree that students should learn basic science content in addition to being actively engaged in the inquiry process. Anne Tweed, 2004 president of the National Science Teachers Association, has this to say about inquiry-based learning in science:

> *Inquiry-based instructional strategies lead to student investigations that can in turn lead to greater conceptual understanding. Direct instruction alone cannot replace the in-depth experience with science concepts that inquiry-based strategies provide. Students must create mental models that connect their learning experiences to the science concepts. Learning cycles that allow students to explore a concept in depth support students' sense-making of their observations* (Tweed, 2004).

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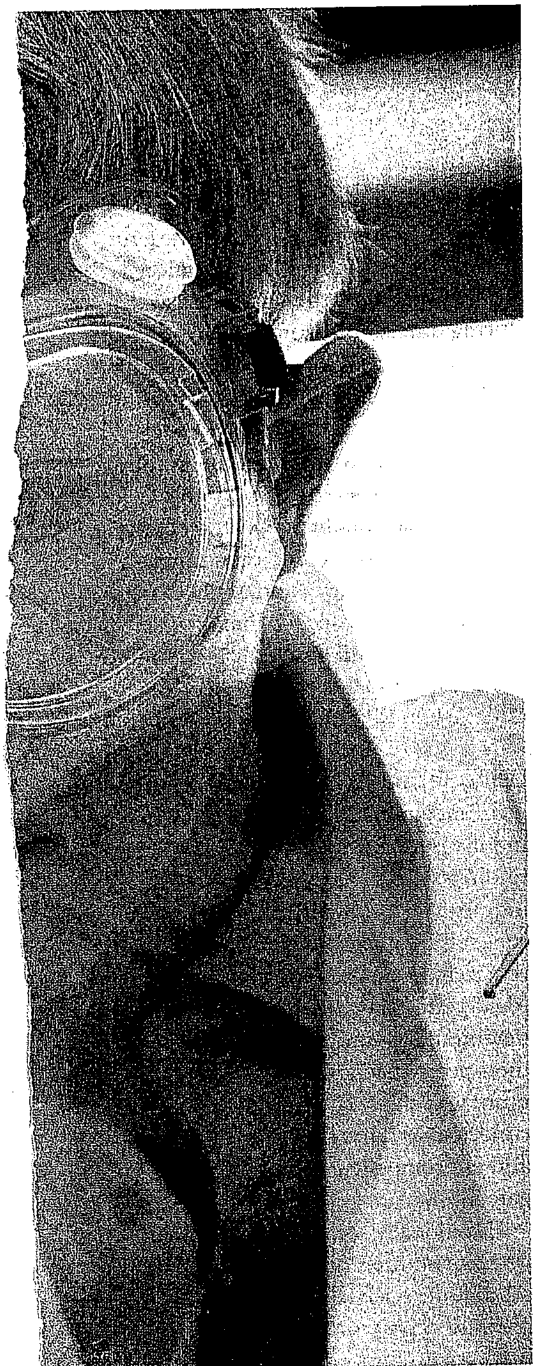

Infusing technology into science education can help clarify ways to use inquiry methods in coordination with education standards—thereby improving the efficiency and viability of the inquiry process.

Science Inquiry

Science inquiry, once synonymous with the scientific method, now subtly differs in several ways. The scientific method outlines a specific linear process during which students conduct experiments, whereas science inquiry allows for more flexibility because it is a continual cycle of questions, student-centered investigations, and further explorations. Implementing the inquiry method into classroom instruction helps students to more closely parallel the processes employed by researchers and scientists (National Science Foundation, 2000).

Science as inquiry, one of eight categories of content standards outlined by the National Science Education Standards, requires students to develop abilities necessary to understand and perform scientific inquiry within the grade clusters K-4, 5-8, and 9-12 (National Academy of Sciences, 2000).

Stages of the Inquiry Process

The inquiry process has five general stages:

1. *Engagement.* The learner, through observation, raises scientifically oriented questions.
2. *Planning.* The learner uses previous research and background knowledge to plan an investigation.
3. *Investigating.* The learner performs guided investigation, experimentation, and observations in an attempt to answer the questions.
4. *Analyzing.* The learner analyzes his or her findings, organizes the data, and makes predictions while evaluating them in light of alternative explanations.
5. *Communicating.* If the conclusions in step 4 do not require repeating the cycle from step 2, the learner communicates and justifies his or her explanation.

After communicating the explanation, the learner might find that the communication process has prompted more questions, thus restarting the cycle.

Engaging the Learner

Engaging the learner is the first phase of the inquiry process. When teachers capture students' attention through demonstrations, movies, and other activities, students begin asking questions. Teachers can use these responses to encourage learners to consider the course of their inquiries and to contemplate questions about scientific concepts, patterns, or phenomena.

As shown in a meta-analysis of effective instructional strategies, activating students' prior knowledge by the use of cues, questions, and advance organizers provides a powerful learning experience by scaffolding previously learned concepts with those they are about to learn (Marzano *et al.*, 2001).

The authors also point out that higher-level questions produce deeper learning than lower-level questions, and that questioning students can be a powerful learning tool in and of itself, prior to a learning experience (Marzano *et al.*, 2001).

The teacher has the most active role and does the most direct instruction during the engagement stage. In subsequent steps, the teacher takes on the role of facilitator or coach, guiding students to meaningful discoveries.

Using Technology to Plan

Planning an investigation is the second phase of the inquiry process. During this phase, the teacher and students typically discuss what they already know, what they want to know, and how they plan to find it. This is also the time to address misconceptions and prepare an investigative plan that includes available materials, technology, and methods.

One of the most useful features of technology is the range of nonlinguistic representations available to a variety of learners. Research shows that the majority of traditional instruction is delivered in linguistic form, either as a lecture or as written material, leaving the learner to create his or her own nonlinguistic representation. Helping students to create nonlinguistic images is an effective instructional strategy that enables learners to better understand and retain new knowledge (Marzano *et al.*, 2001).

Web resources and software provide access to people, places, and simulations that otherwise would be impossible to implement in the classroom. Access to professional knowledge, whether by e-mail or videoconferencing, or on a Web site, provides authentic information for students.

Another benefit to using technology in science instruction is the accessibility of resources to help students practice what they have learned. Research shows that students need an average of 24 practice sessions in order to master 80 percent competency in a new skill (Marzano *et al.,* 2001). Before students can effectively conduct an inquiry, they need some level of background information and basic understanding of a concept.

Exemplary Web sites and software can help students learn the vocabulary and basic concepts of their inquiry topic. For example, students who are about to conduct experiments using certain chemicals must make certain that they know the chemicals' elements and basic reactions. They may visit sites such as the WebElements Periodic Table (**www.webelements.com**), a rich resource that has information, pictures, movies, and possible reactions for each element.

Younger students might use the planetarium application, Stellarium, to see how the moon's rising and setting times change as it goes through its phases. Another excellent resource during this phase of the inquiry process is ExploreLearning's Gizmos (**www.explorelearning.com**). Gizmos are small, interactive applications that help students to better understand science concepts.

Using Technology to Analyze

During the data collection phase of the inquiry process, teachers and students typically discuss effort and performance rubrics for inquiry outcomes. The teacher facilitates the implementation of the learners' investigative plans and guides them in organizing their data and observations.

Using data collection software in this phase enables students to focus on higher-level activities rather than on tedious, low-level data collection activities in which mistakes are often made. For example, in many elementary classrooms students are required to use an analog thermometer to gauge the daily temperature and plot the information onto a graph. When the focus of the lesson is to make predictions based on this data, it is imperative that it be accurate and timely.

During the data collection phase of the inquiry process, learners scrutinize and summarize data and observations, and determine which are relevant by identifying patterns, empirical relationships, and verifiable evidence. Based on their findings, they formulate explanations that may also incorporate scientific laws, theories, and concepts from their earlier research. If necessary, the learners may refocus their research question based on insights gained from new evidence.

There are innumerable methods for students to analyze evidence, form explanations, and make predictions, but the use of graphing software enables them to synthesize a large amount of data into nonlinguistic form. For example, a group of students who are investigating how a location's latitude will affect the length of day during different seasons could use Microsoft Excel to analyze their data. By putting their data into nonlinguistic form, students can begin to answer such questions as: How will the graph look in December? Why is Quito's length of day unaffected by the change in seasons? Why are the icons representing Buenos Aires and Melbourne nearly superimposed? Is there a date when all cities will generally be on the same line? If so, which line? Which date? When will this reoccur?

A Science Inquiry Workshop

To facilitate the inquiry process, teachers can participate in a science inquiry and technology workshop like that offered by the Mid-continent Research for Education and Learning (McREL). The McREL workshop instructs teachers on how to use software, Web resources, and data collection tools to promote the science inquiry process in their classrooms, even with traditionally difficult topics like astronomy.

During the McREL workshop, teachers are introduced to multimedia resources directed toward engaging learners, such as BrainPOP, UnitedStreaming, Bill Nye, and video clips available on the Web. For example, to engage learners prior to investigating bridges, the teacher might show a video clip of "Galloping Gertie," the Tacoma Narrows Bridge that collapsed in 1940.

Teachers also are shown how to use popular organizing and brainstorming applications, like Kidspiration and Inspiration, and to gather questions posed by students after watching a movie or demonstration.

Using Technology to Communicate

A fundamental principle of scientific inquiry is to defend and share one's findings. During the last phase of the inquiry process, learners prepare to report their questions, predictions, research, investigations, and findings. Ideally, they have an opportunity to defend their findings to an audience of their peers, teachers, parents, or community. In this way, the inquiry process continues as others read the findings and are compelled to further investigate, dispute, or revise the findings.

Traditionally, students have been limited to communicating their findings in schoolwide science fairs. Now, they also are able to post their findings online in a variety of ways. For example, they can create documentaries, post their data on Web sites and blogs, or create multimedia presentations to share findings and gather feedback from global audiences.

Technology can provide powerful tools for science inquiry by helping students to ask questions, investigate, and share their findings. When teachers use these tools in science classrooms, they provide optimal learning environments for their 21st century students.

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