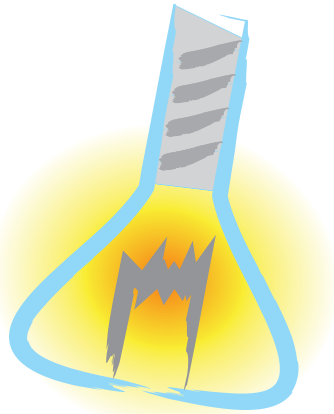
The Art of Scientific Ideas



Teaching and learning strategies that promote creative problem finding

Frank LaBanca and Krista C. Ritchie

"The formulation of a problem is often more important than its solution, which may be merely a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old problems from a new angle, requires imagination and marks real advance in science."

—Einstein and Infeld 1938

Problem solving is a valuable skill in the science classroom (Chi, Glaser, and Rees 1982; Parnes, Noller, and Biondi 1977; Shore et al. 2009). Students often use a variety of inquiry strategies to identify problems and their implications; develop action plans; locate relevant sources, information, and data; and formulate solutions. Problem solving is a logical, analytical, and sometimes creative process. The less tangible, more challenging problem solving process is learning how to ask a good question.

This leads to a critical question: How are problems identified? We very rarely talk about the process for developing a unique and engaging idea for study: *Problem finding* is the ability to identify a problem and consider its alternative views or definitions. This creative process (Dillon 1982; Getzels and Csikszentmihalyi 1976) requires setting objectives, defining purposes, deciding what is interesting, and, ultimately, determining what to study (Leavitt 1976).

To examine problem finding factors that lead to high-quality science fair projects, we empirically studied students who participated in science fairs and were top winners at the state (Connecticut) and international (Intel International Science and Engineering Fair [ISEF]; read more about ISEF in the Rillero article on p. 44) level (LaBanca 2008). We also explored students' personal experiences in inquiry-based science classes that did (i.e., student-directed research classes) and did not (i.e., teacher-directed lab classes such as biology, physics, and chemistry) require them to problem find (Ritchie 2009). The common characteristics that emerged across our studies led to the following practical strategies for teachers and students.

Strategies for teachers

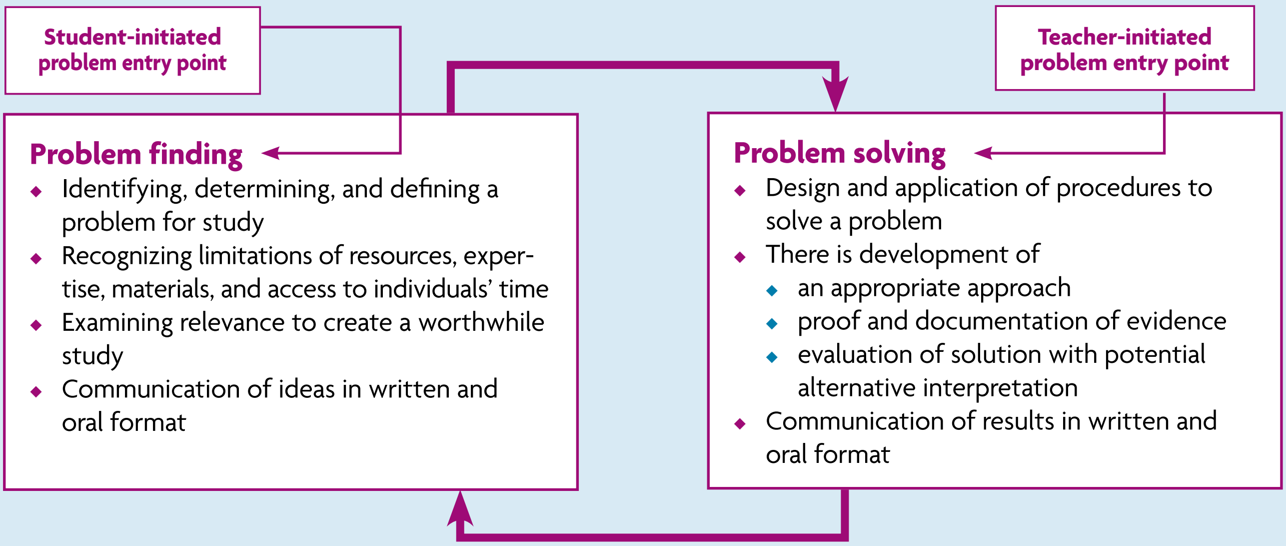
Problem finding takes time, care, and deliberate planning. If teachers and students want to develop quality, high-caliber projects, they must pay great attention to this part of the research process. Below is a list of strategies for teachers.

Stay connected to every project

Get to know your students, their interests, and particular areas of strength. Identify who needs a little extra push to meet deadlines, who needs help with writing, and who needs help with technical aspects of methodology. Each student brings his or her own motivations, experiences, and skill sets to this process.

FIGURE 1

The relationship of problem finding and problem solving in science research.



Let students know what you don't know

One teacher can't be an expert in all areas of science. Let students know that they are becoming the content experts, and help them connect with other teachers or local professors who are subject-matter experts. Students should be encouraged to pursue their interests, not their teacher's.

Manage the student research process

Problem finding includes narrowing a topic or area of interest into a definitive question and ensuring that the student can answer the question. This process involves a great deal of planning, reflection, and knowledge of experimental procedures and methods. Help students shape and refine their questions into something that is answerable and interesting to both themselves and an outside audience. (**Note:** There are regulations that govern the research that students can conduct. Familiarity with Scientific Review Committees, Institutional Review Boards, and Institutional Animal Care and Use Committees is important. Guidelines aligned with the ISEF rules are available online [see "On the web"].)

Instill confidence

Students occasionally doubt their abilities at different times throughout the problem finding process. Stay connected to students and build a relationship that allows them to talk about their insecurities or doubts. Allow students to explain what they know and ask effective questions. This improves focus and defines projects.

Help students set deadlines

Hold at least a few class sessions in which students report on their progress. Formally discussing interests, ideas, and challenges as a lab group is valuable. Facilitating group meeting times will help students set and meet subgoals and take ownership of their work. This is an important scaffolding strategy because students can be overwhelmed by the long-term goals associated with independent projects.

Create an authentic audience

Not all students make it to the national or even the local science fair. But all students who engage in the problem finding process deserve an audience that extends beyond the walls of the classroom. Organize a school conference or science fair and invite students, their parents, and teachers. Make it a formal affair with introductory remarks, formal attire, judges (i.e., people in the local scientific community such as engineers, scientists, teachers, professors, and health care practitioners), and a printed program with titles, brief student biographies, and abstracts of students' projects.

Strategies for students

In many lab-based science classes, the teacher identifies the problem for study due to curricular requirements, time factors, or the scope and goals of particular learning modules. However, when engaging in extended research experiences, the responsibility of identifying a problem shifts to students—creating a sense of ownership. When students pursue independent research, learning expands to include both the problem finding *and* problem solving processes (Figure 1).

The following is a list of research-based, practical recommendations to improve the quality of the problem finding process for students.

Focus your problem on areas of personal interest

Students should identify areas of personal interest and use those interests to generate problems. They can learn about their interests through textbooks, journal articles, and discussions with others. These interests can stem from a variety of places, such as students' value systems or intellectual pursuits already underway in their lives.

For example, in a study conducted by one of the authors, Krista Ritchie (2009), a student expressed a passion for environmental issues. She read about a particular kind of beetle, thought it would be a fun topic, and knew of research being conducted on these beetles. But even with this interest, the student couldn't narrow her topic or figure out a novel approach to her research.

While searching for a new topic, the student read about recombinant growth hormone in cows. Although a vegetarian, she valued the idea of being able to identify such hormones in commercial meat. With that alignment of current science and personal interest, this student found her topic: She explored ways to determine the presence of bovine growth hormones in meat purchased at the grocery store.

Develop written and oral communication skills

Written and oral communication skills require that students learn, synthesize, and reorganize information. Students who develop these skills can share research in an effective fashion and increase their potential success. A variety of individuals should edit students' written work, and practice is key for oral skills. Professional presentation—in look, style, and attitude—is a necessity. Opportunities to share areas of interest and solicit feedback, both in written and oral forms, can promote discussions from which researchable questions flow.

Articulate the project's value

High-quality projects have relevance that extends beyond the classroom walls to an authentic audience. This audience should be a group of individuals who find value in the student's work. Students can and should define that audience (e.g., the state's department of environmental protection, the health services field, astronomers, electrical engineers). The science and engineering community often has a higher level of acceptance and appreciation for student projects that generate novel, valuable knowledge.

Journal about the experience

Scientists keep journals of their progress throughout the research process, including problem finding. Sometimes, they have a flurry of ideas and not enough time to answer all of the potential questions. At other times, this fluidity might not be readily available. Keeping a problem finding journal can stimulate future projects and help students focus on their current projects. It provides students with the opportunity to vet their thinking—what will work, the available resources and existing expertise, and other knowledge they need to acquire.

Problem finding perspectives.

From a student:

"I saw a lot of projects [at the science fair] that were interesting, but they [were] all taking methodology that is out there already and reapplying it to a specific study. And they are great as studies, but in terms of experimental development, it's not like they are finding out anything that others could build on. Knowing the pollution quality of a river is important—it's a good thing to know. But it's not like measuring it is anything new."

From the student's mentor:

"So she's doing something new. That almost, in itself, makes it good, I think. She's addressing a question that no one has addressed. A lot of people try to repeat things others have done. I'm not terribly excited by doing these types of experiments. And neither is she."

From a multipatent-holding engineer and science fair director:

"In many cases, the differentiating factor [for a student's success] is the creativity that is apparent in looking at the work, as opposed to the work. If you have just an absolutely outstanding project that [follows] the scientific method and [has a] perfect laboratory routine and that goes against a loosely organized project that is a brand-new idea, the brand-new idea is going to win."

Be an aggressive information consumer

Before focusing on an answerable research question, students need to know where and how to get information. Reading newspapers, popular science magazines, and journals; conversing with scientists and engineers; and watching science-specific TV and webcasts helps students become consumers of current science. As students learn about their areas of interest, they can further facilitate the process by developing search strategies in scientific journal databases.

Create a support system

The individual teacher and student are not the only ones involved in a great project. Throughout the problem finding process, students need to rely on each other for support. Some students might have parents who can help them, but others might need to find mentorship outside of the school community.

Students can benefit from consulting their school's media specialist, who can help them find information related to their projects. They may also want to consider working backward, using their intended audience as expert consultants. The problem finding support system often transitions to the problem solving phase. Teachers can help facilitate this process, but it is important for students to recognize that they are their own project managers.

Be your own motivator

Motivation is an important factor in the extended research process. Students who show a passion for problem finding and problem solving can pursue ideas with zeal. Not all students have access to a first-class university or industry laboratory to conduct research, but this shouldn't stop them from pursuing research excellence. Meaningful, valuable projects can be completed on shoestring budgets, and an inventive student—regardless of economic, cultural, or social background—can often gain access to the necessary resources and expertise with thoughtful, humble determination.

Manage time effectively

In a science research experience, outside organizations often impose deadlines. Students need to identify how much they can realistically accomplish in a finite time frame with limited expertise and access to experts, supplies, and equipment. Meaningful problems can lead to poor-quality projects if students can't successfully solve them.

The problem finding stage is a critical step in the research process and can't be hurried. This inquiry phase requires considerable time, thought, and resources. When students discover ideas or phenomena that interest them, they need time and support to refine their interests and formulate meaningful, manageable research projects.

Establish a flexible view of inquiry

Some students follow a step-by-step, linear, hypothesis-based experimental protocol. However, students can benefit from a commitment to a meaningful problem, rather than a prescriptive problem solving method, because it affords a level of flexibility. The question should drive the method rather than the reverse. Sometimes pilot experiments help students develop their methodologies, and the outcomes can refine their research questions. Some problems are better solved without formal experimental protocols.

There are many routes to problem solving, such as hypothesis-based, trial-and-error, abstraction, research, lateral thinking, and root-cause analysis. During problem finding, an adaptable, nonrestricted approach can potentially generate more innovative questions because it harnesses a specialized set of knowledge, skills, and dispositions (Shore et al. 2009)—improving the quality and precision of problems.

Conclusion

Problem finding research can provide a creative opportunity for students in the content-specific, laboratory-based science classroom. Creative students who have found and formulated their own problems conduct outstanding research. These students are often bright, eager, resourceful, persistent, and curious—driving and sustaining their efforts to know and understand. They are self-motivated self-starters who are capable of independent learning. Understanding the necessary knowledge, skills, and dispositions for meaningful problem finding will help teachers and students work toward the development of quality projects. ■

Frank LaBanca (frank@labanca.net) *is the director of the Center for 21st Century Skills at EDUCATION CONNECTION in Litchfield, Connecticut, and Krista C. Ritchie* (Krista.Ritchie@iwk.nshealth.ca) *is a consulting scientist at IWK Health Centre in Halifax, Nova Scotia.*

NSTA connections

To read more about hormones, check out the "Cell Structure and Function: The Most Important Molecule" NSTA Science Object. NSTA Science Objects are online, inquiry-based content modules for teachers that are free of charge. For more information, visit *http://learningcenter.org/products/science_objects.aspx.*

On the web

Guidelines aligned with the Intel International Science and Engineering Fair (ISEF) rules: *www.ctsciencefair.org/media/ezpath.pdf*

ISEF rules: *http://societyforscience.org/isef/about/rules_regulations.asp*

References

Chi, M.T.H., R. Glaser, and E. Rees. 1982. Expertise in problem solving. In *Advances in the psychology of human intelligence,* Vol. 1, ed. R.J. Sternberg, 7–75. Hillsdale, NJ: Lawrence Erlbaum Associates.

Dillon, J.T. 1982. Problem finding and solving. *The Journal of Creative Behavior* 16 (2): 97–111.

Einstein, A., and L. Infeld. 1938. *The evolution of physics*. New York: Simon and Schuster.

Getzels, J., and M. Csikszentmihalyi. 1976. *The creative vision: A longitudinal study of problem finding in art*. New York: Wiley & Sons.

LaBanca, F. 2008. Impact of problem finding on the quality of authentic open inquiry science research projects. EdD diss., Western Connecticut State University.

Leavitt, H.J. 1976. Problem finding, problem solving, and solution implementing: Creativity in the context of working problems through. *UCLA Educator* 18 (2): 1–5.

Parnes, S.J., R.B. Noller, and A.M. Biondi. 1977. *Guide to creative action*. New York: Charles Scribner's Son.

Ritchie, K.C. 2009. The process of problem finding in inquiry education: A focus on students' experiences. PhD diss., McGill University.

Shore, B.M., C. Birlean, C.L. Walker, K.C. Ritchie, F. LaBanca, and M.W. Aulls. 2009. Inquiry literacy: A proposal for a neologism. *LEARNing Landscapes* 3 (1): 139–156.