strong incentive to maintain the status quo. Why remove a relatively flexible source of income, lab fees, from your budget by changing the way introductory labs are taught or by eliminating labs altogether?

Finally, laboratories, even as cook book labs, are generally difficult to bring into production. A thousand and one things can and do go wrong. To paraphrase the late Art Linkletter, "students do the darndest things." From mixing the wrong chemicals to the inevitable spills to being involved in serious accidents, almost anything can and does happen in a lab full of students. To be sure, this is part of learning how to function in a laboratory environment but, it also means that instructors tend to stick with well-established labs that minimize the potential for chaos. This generally means that labs are designed and written as simply as possible, providing students with step by step instructions throughout each experiment right to the experimental conclusion. If the solution turns red you did the experiment right if not, repeat steps 1 through 5. This is far removed from the trial and error associated with real labs. The control and predictability of step by step laboratory protocols has a further advantage of limiting student complaints, an important consideration for the tenure and promotion process. Students do not like uncertainty and often reflect this in course evaluations. Real science is full of uncertainty. The closer teaching labs get to "real labs" the greater the uncertainty in experimental outcomes. Students following traditional laboratory instructions have become comfortable knowing what they have to do to get a grade. Being graded on an outcome based on a defined process provides students a level of comfort. These factors make it difficult for faculty to change the types of labs offered and the way labs are taught. Generally speaking, new labs take a lot of effort to design, test and implement and are usually associated with a higher number of student complaints, especially if they are problem based or open ended. In other words, the rewards for changing labs are few while the penalties can be significant, including poor tenure review and havingless time for research and grant writing among them. Indeed, looking at the cost benefit ratio, the costs of changing labs are often significant relative to the benefits gained by a faculty member for doing so.

So, where does all of this leave us? First of all, change may come despite many of the issues just described with perhaps the biggest driver of change being the length and depth of the "Great Recession." Indeed, the *Chronicle* has highlighted a number of these moves (Chronicle of Higher Education, *Budget Cuts Force Chemistry Department to Hold Some Labs Online*, Oct. 8, 2010) and as the impact of the recession continues, we will likely see other forced changes to the science laboratory curriculum. But is this all bad? As the saying goes, "crisis creates opportunity for change," and nowhere is there more opportunity or need for change than in the way laboratory-based science is taught. However, the problem with crisis driven change is that more often than not, the change we see is in efficiencies — that is, doing the same or similar things only cheaper. Rarely does this result in the types of change that bring about a fundamentally new paradigm, in this case a new way of teaching laboratory science. This is particularly true given that the current bricks and mortar model of laboratory education represents the gold standard by which all possible alternatives must be judged. And it is true that few, if any, of the alternative strategies for laboratory-based education, such as the use of lab kits, remote instrumentation, virtual and online labs, can replicate the traditional "hands-on" laboratory. But should they? Is it really desirable to replicate traditional "hands-on" labs using these alternative strategies or should educators be trying to use these approaches to create an entirely new laboratory teaching and learning paradigm?

In rethinking the traditional views of science education, educators and administrators should be focusing on the things these alternate strategies make possible. For example, a significant advantage of an online remote laboratory experience that incorporates remote instrumentation over its brick-and-mortar counterpart is that online laboratories do not have to be confined within defined timeframes (typically two- or three-hour time blocks). This means that online laboratory activities can be less prescriptive in nature, delivered with greater

flexibility, and can provide multiple opportunities for students to consider and modify experimental conditions, reinterpret results, and reflect on experimental outcomes. The ability to repeat, reinterpret, and reflect allows the online laboratory experience to be more representative of the way science is actually conducted. The use of prepackaged science kits that allow students to conduct experiments at home or in the dorm has been shown to draw family members and roommates into the experiments activities. This begs the question: can conducting labs outside the traditional bricks and mortar laboratory be a pathway to greater science literacy for non-scientists?

The bottom line is that instead of replicating traditional labs, these strategies can and should be used in new and/or complementary ways to reshape education and training in the sciences and provide largely untapped opportunities to engage students in ways that go far beyond what is possible in traditional labs. Embracing the capabilities made possible by these alternative strategies represent a significant departure from the traditional belief that science must be taught as a series of predetermined "hands-on" activities conducted within restricted spaces and defined timeframes. Rather than simply moving students through a series of traditional "cookbook-style" activities, in our view the teaching laboratory has the potential to be shifted to one of providing students with a "laboratory experience" designed around associated learning goals and resources. This new paradigm includes access to and us of laboratory kits, remote instrumentation, virtual simulations and other web-based resources, as well as the use of a variety of social networking tools that promote collaboration, information sharing, timely feedback on student learning and on-going assessment. This model of science education incorporates the collective resources and tools available outside the traditional teaching laboratory to engage students in the scientific process, support their learning needs, and promote a culture of scientific research, learning and discovery.

However, designers and users of alternative lab strategies should also avoid the temptation of offering students too much. From YouTube videos, to podcasts, to virtual simulations, to Second Life activities and beyond, it is important to remain cautious about how we conduct educational labs while at the same time fully exploiting the available resources to effectively engage our students. The instructor's role and responsibility for creating and implementing a quality laboratory experience is an essential element of this change. As far back as 1886, Ira Remsen, the first Chemistry Department Chair at Johns Hopkins University and later its President, stated, "It behooves those who are convinced of the great advantages to be derived from good laboratory courses to see to it that these courses are conscientiously conducted." Translated using today's educational language, this statement underscores the importance that teaching laboratories have clear learning objectives, thoughtful instructional design, pedagogically relevant activities, and appropriate evaluation and assessment processes — Crucial elements frequently missing from the traditional teaching laboratories of today. Considering the enormous pressures on undergraduate science programs, should we continue to provide life support for the undergraduate teaching laboratory with its traditions, infrastructure costs, and hidden economies or is it time to change the status quo and seriously consider alternatives?