Commentary

What's Wrong with Cookbooks? A Reply to Ault[1]

by Kereen Monteyne and Mark S. Cracolice*

Cooks may use cookbooks, and cooks may like cookbooks, but should students be cooking in the chemistry lab? In a recent article by Addison Ault in this *Journal (1),* the argument is made that chemistry, like cooking, is best experienced by following a recipe. We disagree. Cooking, like chemistry, is a complex and creative endeavor that requires many skills beyond those developed from merely following a recipe.

Many of us can recall our first foray into the kitchen where we carefully leveled off one cup of sugar and used an actual measuring spoon to obtain three tablespoons of cocoa powder. If we followed the recipe to the letter, we experienced the thrill of success when the end result was not only appealing, but edible. Similarly, students' first experience in the chemistry lab should be structured with clear and safe instructions that increase their chance of success. Over time, our forays into the kitchen became more bold as we tried more complicated recipes (like tiramisu) and discovered the function of each of the ingredients (Does it have to be egg yolks? What happens if we mix in egg whites?). Our creativity in and conceptual understanding of cooking grew as we evaluated each of our successes and failures. Similarly, our ability to propose and test the effect of using different ingredients or different procedures grew as we experimented beyond the bounds of the original recipe. But do students using cookbook-type lab materials develop creativity, conceptual understanding, or thinking skills? The research literature in science education provides some insight into the nature and effectiveness of cookbook labs and answers the question with a definite *no*.

Cookbook labs, also known as traditional or verification labs, use highly structured materials to verify a concept presented previously in lecture or in a pre-lab reading. For example, through a detailed introduction and fill-in-the-blank data collection and analysis, students discover that there *really* are five moles of water for each mole of copper(II) sulfate pentahydrate, just as we, the experts, told them in advance. Students in cookbook labs mindlessly follow written instructions *(2, 3)*, with their primary concern being finishing the lab *(4–7)*. Is this what we want students to experience in the chemistry lab? Does this reflect the nature of scientific inquiry? While we agree with Ault that the novice student requires a recipe, we disagree that the cookbook labs can be a "point of departure… [to] develop skills and provide insight". It is not *how* the data are collected, but rather what is done with the data afterwards that is most important.

In contrast to cookbook labs that provide detailed instructions for data analysis, inquiry labs follow a data-to-concepts approach where students are expected to identify and explain the pattern in the data collected *(8–11)*. In doing so, students acquire many of the skills (e.g., identifying and controlling variables, using proportional relationships) that cannot be developed by placing a number in a box or using a provided mathematical formula. Inquiry labs help students to develop these thinking skills, as well as to develop conceptual understanding and positive attitudes towards science more effectively than the cookbook laboratory *(12–14)*. Unfortunately, even though research shows the benefits of inquiry-based laboratories as compared to cookbook labs, a survey found that only eight percent of ACS-accredited institutions use inquiry materials in lab *(15)*. The barriers to implementation of an inquiry curriculum may seem insurmountable (e.g., lack of faculty experience or know-how to create the materials, inexperienced teaching assistants), but materials *(16–19)* and information resources *(20–23)* are available to aid the transition.

Ault poked fun at inquiry labs by comparing them to asking a child to discover how to make tiramisu from its ingredients, with no further instruction than showing her the locations of utensils. If laboratory or culinary arts instruction was this simple, there would be many unemployed instructors and legions of talented chemists and chefs! A key element of guided inquiry is that *data analysis* is left to the student, but *not* the data collection. The process of analysis is precisely what defines inquiry and creates an environment in which students have the opportunity to develop their thinking skills and conceptual understandings. It is also critical to have a knowledgeable laboratory instructor who can mediate students' thinking skills development and knowledge acquisition. With meaningful experiences in guided inquiry, as with experience in cooking, students can begin to propose and test their own hypotheses in a manner similar to practicing scientists and professional chefs.

Our conclusion was eloquently stated by Charen *(24)* more than thirty years ago in reference to high school science. It is also true for college: "Traditionally, science curricula in the high schools of our nation have not been directed toward the development of the ability to do critical thinking (problem-solving). Even the laboratory, admirably suited to such development, has not been exploited, its natural assets being wasted while being generally loaded with 'kitchen-type' laboratory exercises without real significance."

What's wrong with cookbooks in the chemistry laboratory? Everything!

Note

1. Ault's response to this Commentary appears on p 1569 of this issue.

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