What are the consequences of chemical activity?

(the question of Benefits-Costs-Risks)

The decisions people make daily about interacting with substances involve the explicit or implicit evaluation of the merits and consequences of those interactions. For example, when buying milk at a supermarket, one is often faced with the choice of milk in wax-lined cardboard or in plastic containers. A careful consumer might consider questions such as: Which of these containers is better at preventing spoilage? Do the containers add any dangerous chemicals to the milk? Which container may be recycled? Is the price difference between the milks in each of the containers worth my worrying about these issues? These are questions about the benefits, costs, and risks (BCR) of using chemical products or engaging in chemical activity that require the application of chemical thinking and the integration of different types of knowledge to be answered. For example, answering the question about which milk container to purchase might involve considering environmental issues (e.g., where do the materials to make the containers come from and is their production environmentally sustainable?), health impacts (e.g., are there trace substances in the milk from either container that might interfere with certain medicines taken by my family members?), economic matters (e.g., which milk container is more affordable?), and political considerations (e.g., which container uses sourcing that would help the economic situation of people I care about in my country?).

Chemistry is typically taught in aseptic and sterile ways, without much discussion of the social, environmental, economic, and political implications of generating and using chemical products. This is highly problematic given the central role and major impacts that chemical activities have in modern societies. It is thus critical to create multiple opportunities for students to develop and apply chemical thinking while engaged in the analysis of problems of relevance to them and their communities.

Unpacking

Most topics in chemistry can be connected to products or processes of relevance in daily life and to decisions with important consequences at the individual and social levels. When designing chemistry lessons, it is critical to identify the different relevant contexts in which the central concepts and ideas to be discussed support BCR analysis and decision making. This type of unpacking in lesson planning is facilitated if we think beyond the chemical nature of the materials or processes in our surroundings and consider also their life-cycle. In other words, we pay attention to the social, environmental, health, economic, and social burdens of producing, consuming, and disposing of the different chemical products and processes on which we depend. We can create rich opportunities for students to learn central concepts and ideas in chemistry by challenging students to make and justify decisions that have actual consequences in modern societies.

People are often confronted with choices in the products they use that are not easy to make and are not trivial to justify. One may think, for example, that it is obvious that using paper bags is a better option than using plastic bags when going to the supermarket. Nevertheless, a life-cycle analysis of each of these options, taking into consideration the material and energetic inputs involved in producing and disposing of each type of bag, may reveal a surprising answer. This type of analysis requires chemical thinking related to structure-property relationships, chemical causality and chemical control. Similarly, deciding whether using gasoline or ethanol as automobile fuels, or driving cars with combustion versus electric engines, or consuming organic versus genetically modified food demands an in-depth investigation of the diverse types of impacts of transforming and consuming different types of natural resources, and application of different dimensions of chemical thinking. Activities in which students are asked to evaluate the benefits, costs, and risks of different options open the door to the discussion of the central ideas we want our students to learn. For example, while evaluating different automobile fuels, students can learn about conservation of matter and energy transfer and dissipation during chemical reactions in a context in which these ideas matter.

Eliciting and Exploring

As we work with students in BCR analysis, it is important to elicit their knowledge and beliefs about the issues under discussion. Given the intuitive assumptions and beliefs known to guide people's BCR reasoning, it is important to make students' thinking visible when they are asked to analyze the social, environmental, health, economic, and political impacts of competing choices. Students should become aware not only of their own beliefs and potential biases in decision making, but also should recognize that other people may be guided by different assumptions. For example, research suggests that individuals tend to selectively credit or dismiss evidence of BCR based on personal values that they share with others rather than on scientific knowledge. Science learners have been found to rely on emotive and intuitive resources when analyzing socio-scientific issues, independently of their level of content knowledge about a subject. People tend to exhibit strong preferences for products and processes considered to be “natural” over “artificial", as natural substances and processes are often linked to a subjective impression of goodness, while the products of human intervention are judged more negatively. Positive or negative emotions prompted by words, images, objects, or events affect judgments regarding BCR and influence people’s preferences and choices. Eliciting, discussing, and reflecting on these intuitive beliefs and biases is critical for students to develop critical thinking skills that all scientifically literate citizens should have.

Advancing and Connecting

Engaging students in BCR analysis and decision making is a great avenue to develop core science practices such as asking questions and defining problems, analyzing and interpreting data, constructing explanations and designing solutions, and engaging in argument from evidence. The types of decisions that students will have to make using their chemical thinking require weighing the effects of multiple factors, and the comparative analysis of different types of data. This type of reasoning should be carefully scaffolded to facilitate discrimination of relevant information and its integration in decision making. Given the major role that affective issues play in BCR analysis, it is important that teachers create a learning environment in which all expressed ideas are respected and evaluated in consideration of existing evidence.