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Chemistry Education: Ten Heuristics To Tame

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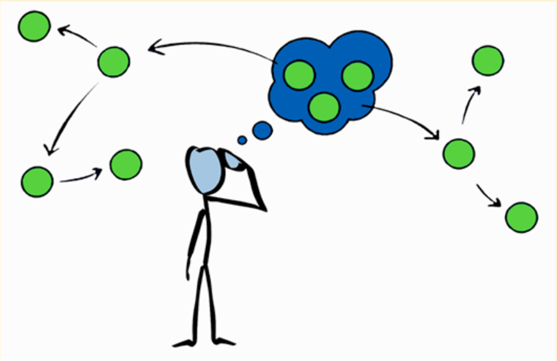
ABSTRACT: Students in our chemistry classes often generate shallow responses to our questions and problems. They fail to recognize relevant cues in making judgments and decisions about the properties of chemical substances and processes, and make hasty generalizations that frequently lead them astray. Results from research in the psychology of decision making can help us better understand how students approach chemistry tasks under conditions of limited knowledge, time, or motivation. In this contribution, I describe 10 cognitive heuristics that are often responsible for biases in student thinking. Helping students tame these heuristics may allow us to foster more meaningful learning in chemistry classrooms.



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INTRODUCTION

Our understanding of the many challenges that chemistry teachers and instructors face to promote meaningful learning in the classroom has increased considerably in the past 40 years. In this period we have learned, for example, that the level of cognitive development of our students influences the extent to which they may reason with and about abstract chemistry concepts.[1,2] We have also realized that students' prior knowledge plays a central role in the construction of new understandings,[3−5] and that conceptual change demands active and reflective engagement with the content.[6,7] Research studies have shown that understanding students' thinking is not easy and may be subject to different interpretations,[6] and that affective issues may strongly influence students' performance.[8] In general, research in science and chemistry education has directed us to be mindful of the cognitive and affective demands that our instructional activities impose on learners,[9,10] to carefully scaffold student learning[11] along well designed learning progressions,[12] and to create rich and diverse learning opportunities for students to connect concepts and ideas to build a robust chemistry knowledge structure.[13]

Our current views of effective chemistry education have been strongly influenced by work in other fields, from developmental psychology to cognitive science to science education. For example, the work of Jean Piaget on children's intellectual development challenged us to pay careful attention to the nature of the concepts and ideas that we teach.[1,2] The ideas of David Ausubel on meaningful learning led us to question the role of rote memorization in chemistry education.[3,5] The work on alternative conceptions in science education focused our attention on students' everyday knowledge and its critical role in the learning process.[14,15] Basic tenets from Information Processing Theory have shaped how many of us think about the role of attention, working memory, and long-term memory when students engage in solving chemistry problems.[9,10]

In recent years, my work in chemistry education has been guided and informed by the bodies of research described above. However, my struggle to make sense of student reasoning in chemistry has led me to seek for answers in other areas, including research in judgment and decision making[16−19] that has not been typically considered by chemistry educators. These types of studies provide insights into how people reason under conditions of limited time and knowledge which are similar to those faced by students enrolled in chemistry courses. Although most work in this area has focused on exploring reasoning in personal and social contexts, the results are of central relevance to chemistry teaching.

The solution to many questions and problems in our discipline demands making comparisons between the properties of two or more systems, or between the properties of the same system at different times or under different conditions. The outcome of such comparisons allows us to make decisions about the relative value of physical (e.g., density, boiling point) and chemical (e.g., acid strength, nucleophilicity) properties of substances, or the relative rate and extent of different chemical reactions. Thus, proper judgment and decision making are critical aspects of chemical thinking and relevant results from social psychology have transformed the way in which I now approach the analysis of my students' reasoning. What in the past I saw as random guessing in generating an answer, now I often interpret as the natural outcome of intuitive reasoning heuristics used by all people in their daily lives. What I judged to be the product of shallow test taking strategies during an exam, now I can see as the result of short-cut reasoning procedures commonly used by humans to make decisions

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under uncertainty. What seemed to be easily corrected misunderstandings, now I use as cues to look for deeper reasoning constraints.

Results from research in human judgment and decision making have become the subject of several popular science books in recent years.[18,19] Thus, it is not my intention to use this contribution to present a comprehensive summary of major insights in the field. My main goal is to highlight what I see as pervasive ways of reasoning with major implications for chemistry education. Given that human judgment and decision making seem to involve a variety of cognitive processes, I decided to center this paper on the description of 10 heuristics that play a central role in students' reasoning about the properties of chemical substances and reactions. But before we get there, let me introduce some important concepts and ideas.

■ OF TWO MINDS

People's approaches to judgment and decision-making have been analyzed from a variety of research perspectives.[16,17] One common theoretical framework, known as dual-process theory, proposes that the human mind has the ability to engage in two distinct types of reasoning often labeled Type 1 and Type 2.[20,21] The first of these types of thinking includes processes that make little use of working memory and tend to be automatic, fast, and rather independent of cognitive ability. On the other hand, Type 2 processes require working memory to function and tend to be slow, sequential, and their application and performance often correlate with measures of general intelligence. One of the defining characteristics of Type 1 processes is that they are autonomous, not requiring controlled attention for their triggering and application. This category of cognitive processes includes both innately specified reasoning procedures and strategies learned to the point of automaticity; they correspond to our common sense notion of intuitive thinking. Type 2 processes are assumed to enable hypothetical thinking and mental simulation. Their application requires conscious intervention and demands cognitive effort; they correspond to what we commonly identify as analytical or reflective thinking.

Existing evidence suggests that Type 1 processes are triggered rapidly and with little effort when we confront novel problems or situations.[20,21] They seem to be the default response of our cognitive system, particularly under conditions of limited time, knowledge, or motivation. In daily life, Type 1 reasoning often allows us to make reasonable decisions or generate satisfactory answers without much cognitive load. However, Type 1 processes also seem to be responsible for a variety of cognitive biases in human reasoning;[16] our intuitive choices may work as cognitive illusions that lead us astray.[18] Sound judgment and decision making sometimes require an override of default intuitions and their replacement by effective analytical (Type 2) reasoning. Type 2 interventions may inhibit or modify the responses generated by Type 1 processes depending on the extent to which the answer is judged unsatisfactory. These types of interventions are more likely to occur when people are metacognitive and have strong relevant knowledge, high cognitive ability, or a disposition to be reflective. Type 1 processing can be expected to dominate when a person has less knowledge, capacity or motivation to work and do well in a task.[20,21]

Many Type 1 processes can be seen as shortcut reasoning strategies, often called heuristics, that reduce the information-processing load.[16,18,22] In general, heuristics simplify reasoning by reducing the number of cues used in making a decision or by providing implicit rules of thumb for how and where to look for information, when to stop the search, and what to do with the results.[17,22] They can be conceived as cognitive tools that allow us to effectively solve particular tasks in specific situations. They are said to be ecologically rational because they make efficient use of the information readily available in specific task environments. By drawing on core cognitive capacities (e.g., vision, memory) and by taking advantage of regularities in the structure of our environment, heuristics can generate accurate decisions under conditions of limited time, knowledge, and computational power.[17] Nevertheless, they may also be responsible for systematic errors in judgment (cognitive biases), particularly when relevant decision-making cues are implicit rather than explicit, or unknown to people.[16,18]

■ TEN HEURISTICS

Although most research on heuristics in decision-making has been completed in nonacademic contexts, there is evidence that Type 1 reasoning plays a central role in the classroom. Studies in mathematics,[23,24] physics,[25] and chemistry[26−32] education indicate that students' answers are often the result of the application of heuristic reasoning triggered by the surface features of academic tasks, rather than the product of analytical thinking based on central concepts and ideas in a given discipline. In this section, I describe and discuss 10 reasoning strategies that seem to be responsible for many of the hasty answers generated by students in our chemistry courses. It is not my intention to portray students' reasoning as deeply flawed and biased. On the contrary, my goal is to highlight that many of the judgment errors that students make are the result of cognitive processes that are inherently human. Actually, heuristic strategies are highly productive in daily life when applied using the proper cues in the right contexts. Experts in a field rely on a variety of heuristics to make quick and efficient decisions, but they have learned to use them efficiently and properly.[33] It is likely that people's minds would be paralyzed if forced to make decisions using Type 2 processes all of the time. Nevertheless, the application of heuristics can result in reasoning biases that may be difficult to avoid. Becoming aware of these issues can help instructors better support student learning and avoid creating conditions that reinforce or inadvertently reward unreflective reasoning.

Human reasoning is complex, resulting from the integration of multiple processes. It is thus challenging to individually characterize cognitive processes that often work in tandem or conjunction when people engage in judgment and decision making. Nevertheless, I find it useful to try to unpack or deconstruct such complexity to facilitate reflection on learning and teaching issues. Table 1 lists the 10 cognitive processes that I seek to analyze. All of them play an important role in human reasoning and are rather useful when used appropriately. Problems arise when people fail to recognize the inadequacy of these forms of reasoning in particular contexts and unreflectively accept the first quick answers that such cognitive strategies automatically generate. The first three associative processes included in Table 1 (i.e., Associative Activation, Fluency, and Attribute Substitution) are particularly relevant because they often work in tandem to support all other types of heuristic reasoning.[34] In fact, it is difficult to present concrete examples of one of these three processes without including the other two. It is also important to point out that some heuristics are related to each other, such as processes 4 through 8 in

Table 1. Ten Major Cognitive Processes That May Result in Systematic Biases in Judgment and Decision Making

Fundamental Associative Processes	1. Associative Activation
	2. Fluency
	3. Attribute Substitution
Inductive Judgments	4. One-Reason Decision Making
	5. Surface Similarity
	6. Recognition
	7. Generalization
	8. Rigidity
Affective Judgments	9. Overconfidence
	10. Affect

Table 1 that support inductive reasoning and processes 9 and 10 that involve affective judgments.

FUNDAMENTAL ASSOCIATIVE PROCESSES

Associative Activation

Human memory strongly relies on the mental association of objects, properties, or events frequently seen or experienced together.[34] The links formed in people's minds can be pretty specific, like the association between someone's face and their name, or rather general, like those resulting from the abstraction of patterns of behavior from multiple exposure to certain types of events (similar to what other authors have identified as phenomenological primitives[35] or reasoning primitives[36]). For example, diverse experiences with moving objects often lead people to build general correlations such as "the higher the speed, the shorter the time" or the "longer the distance, the longer the time." Associations often involve links not only between concepts, but among emotions, motor responses, and mental goals. Mental constructs that have been linked to certain objects or events are likely to be automatically brought to mind whenever someone perceives things that remind her or him of such objects or events. For example, the smell of rancid food evokes a sensation of vomit that triggers a facial expression of disgust that decreases the level of tolerance to the bad smell.[34]

Associative processing uses linked constructs in the mind to fill in information, quickly and automatically, in situations that resemble past observations or experiences. Past knowledge may be retrieved and used based on irrelevant or superficial similarities to current conditions. In general, judgment and decision making involves weighing a variety of items of information. Cognitive biases arise when some aspects of the information are systematically overweighted while others are underweighed or neglected, relative to an established criterion of proper judgment.[34] Research indicates that strongly activated information is likely to be given more weight than it deserves, while relevant knowledge that is weakly or not activated will be neglected. In general, one can expect decision making to rely on existing and "on-the-fly" associations between pieces of activated knowledge.

Imagine, for example, that we asked students to predict which of two different molecular compounds (e.g., ethane and ethanol) will produce more energy upon combustion based on the analysis of their chemical formulas. Looking at the information provided, one student may notice a difference in the number of oxygen atoms present in the molecules of each substance. Thinking about oxygen may trigger the association that "oxygen is needed or is involved in combustion." The concept of combustion is likely to be associated with the production of energy. In consequence, the student may quickly but wrongly judge that the more atoms of oxygen in a molecule, the larger the energy of combustion. Research in chemistry education suggests that this type of associative chain of reasoning is not uncommon among students, even after completing one or more chemistry courses.[29−32] Many of these "on-the-fly" associations take the form of direct (More A-More B) or inverse (More A-Less B) correlations[23] built upon activated knowledge. As discussed below, which properties may be correlated depends on the nature of the cues that are more salient and processed more quickly (or more fluently) by students.

Processing Fluency

Not all of the information presented in a problem or a situation is processed with the same easiness by the mind. For novices in a field, salient explicit features are more easily processed than more implicit cues. Similarly, not all tasks requiring retrieval of similar content are perceived equally (e.g., changes in the way a text is presented may increase perception of difficulty independently of its content). Processing fluency refers to the subjective experience of the ease or difficulty with which a cognitive task is accomplished.[34,37] Fluency experiences are determined by the effort demanded by diverse cognitive processes, including but not limited to perception, memory, and linguistic processing. Processing fluency can be seen as a metacognitive experience about the effort of our thoughts and seems to have a significant influence on people's judgments across a broad range of contexts. For example, people associate fluency with truth, judging statements that are easier to read as truer than those written using uncommon fonts or words. They also rate visually fluent images as more aesthetically pleasing than identical stimuli using less contrastive backgrounds. People also tend to feel greater confidence in their performance when confronting tasks perceived as more fluent (e.g., written in a clearer font).[37]

The cues that are easier to notice and process by a given student can be expected to influence her or his responses in a given task, particularly if such features can be somehow associated with targeted variables in the problem. In general, in the presence of competing plausible factors upon which to base an answer, students can be expected to select the feature that is processed the fastest (i.e., processed more fluently).[25] Consider a case in which students are asked to judge the relative acid strength of H_2S and HBr. A novice learner may quickly notice the difference in number of hydrogen atoms in each of the molecules (explicit cue). Attention to this feature may trigger a vague association (i.e., associative activation) between acidity and hydrogen, leading the student to incorrectly claim that H_2S should be a stronger acid because it has more hydrogens (More A-More B). A different student may more rapidly notice the difference in size or weight between sulfur and bromine atoms, and decide that HBr is the strongest acid due to an intuitive association between larger size/weight and more physical strength (providing the correct answer based on wrong reasons). Answers based on features that are first noticed are prototypical of the responses provided by a significant portion of college students interviewed in our research studies.[29,30,32]

Attribute Substitution

People have the ability to quickly come up with intuitive answers to difficult questions, without going deep into conceptual issues. Associative processing generates a response through "attribute substitution" which can be described as

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follows: The judgment of a target attribute automatically triggers the evaluation of associated attributes in the mind. If one of these attributes is more readily accessible, it could be used as a substitute in making the decision. The answer to a simpler (and more accessible) question is then used as a replacement for the response to the more difficult query.[34,38] Given that the associative system does not keep track of the source of our impressions, attribute substitution tends to occur without conscious awareness.. Consider, for example, that someone asked you to evaluate whether a colleague is generous. Without any hard evidence ready at hand, it is likely that your judgment will be based on your evaluation of other associated dimensions, such as whether this person is warm or friendly. The question that your mind then answers becomes, is my colleague friendly? instead of, is this person generous?

The combination of attribute substitution with associative activation and fluency can be used to make sense of a significant proportion of the incorrect or naïve responses generated by college chemistry students in diverse research studies.[29−32] Initial answers generated by novice learners are likely to be triggered by the most explicit features of a task, such as differences in the numbers and types of atoms present in the chemical formulas of the substances under consideration, or the magnitude of numerical changes in given quantities. These are the most accessible and easily processed features (fluency). These cues will activate related knowledge through associative activation. The more strongly activated information, which will likely correspond to general intuitive correlations (e.g., the heavier an object, the more stable it is) and vaguely remembered chemistry associations (e.g., hydrogen is somehow related to acids), will have a large weight on judgments and decisions. Evaluation of associated attributes will then be used to substitute the targeted assessment, and students will end answering a different question (e.g., when asked, which substance, NaF or NaBr, has a higher melting point? they may substitute the question by, which substance is heavier and more resistant to change?[29]).

■ INDUCTIVE JUDGMENTS

One-Reason Decision Making

Humans do not only substitute less accessible attributes by associated readily available features, but tend to reduce the number of factors that they analyze when making judgments and decisions. In general, people simplify reasoning by using one single cue or factor, frequently the first feature that can be used to provide a plausible answer.[17,39] When applying this "one-reason decision making" heuristic, individuals tend to follow these basic steps: (a) search for cues one at a time to differentiate between options (e.g., weight or electronegativity of atoms involved), (b) compare values of the selected cue for each alternative (e.g., which atom is heavier or more electronegative), and (c) stop the search when a cue is found that can be used to make a choice between options. In general, the final decision is based on selecting the option with the higher cue value on the selected criterion (e.g., it has the heaviest atom). This tendency to simplify reasoning by focusing on one single variable and neglecting others has been highlighted by different researchers in science education.[40,41] In chemistry, where many judgments about the properties and changes of matter depend on the simultaneous consideration of several variables, this problem is pervasive. For example, we have multiple students making decisions about molecular polarity based solely on considerations of bond polarity, ignoring molecular geometry.[41] We find them making judgments about chemical reactivity by considering only the electronegativity of the atoms involved.[32] Similarly, we see them making predictions about changes in thermodynamic properties, with utter disregard of the conditions in which processes take place.[40]

Surface Similarity

People often assume that objects or events that resemble each other on first appearances are members of the same category, and thus they share similar properties, behaviors, and inner structures.[38,42] For example, they assume that all animals that resemble a bird can fly. This "similarity heuristic" is quite powerful in daily life because in many instances appearances are not deceiving. This cognitive strategy helps people reduce the number of cues to consider in making decisions and the difficulty associated with retrieving and integrating additional information about the systems under analysis. Unfortunately, reliance on surface similarity when comparing the properties of chemical substances often leads students astray because relevant similarities tend to be implicit rather than explicit, and appearances are actually misleading. For example, the presence of an OH group in the chemical formula of a compound cannot be used to decide whether the substance is a base, or an alcohol, without further analysis. Similarly, the presence of Cl in both HCl and NaCl should not lead us to assume that these two compounds have similar properties. Nevertheless, this type of reasoning seems to be quite common among novice chemistry students.[29−32]

Recognition

When making judgments and decisions, people often rely on the information that is easier to retrieve from memory, either because it is computed quickly or it has been reinforced by frequent exposure (it is familiar and readily available). Objects or events that are recognized have a strong influence over the decisions that people make because they tend to apply a "recognition heuristic" of the form: If one of several objects is recognized and the others are not, then infer that the recognized object has the higher value with respect to the criterion. For example, individuals asked to choose the largest cities among a set of choices are inclined to select those whose names they recognize.[43] This heuristic uses recognition of an entity as a decision cue, particularly when there is a strong association between the recognized object (e.g., NaCl) and the judged quality (e.g., selecting the substance most soluble in water). Results from our research suggest that students frequently use recognized substances or reactions as anchors in making comparisons.[29,30] That is, the recognized entity is placed at the top or at the bottom of the ranking, using the degree of similarity to this anchor to complete other placements. For example, when comparing the solubility of NaCl, NaBr, and BaO in water, NaCl, a widely recognized soluble substance, will likely be judged as more soluble than NaBr and BaO; in turn, NaBr will be ranked in second position because of its similarity to NaCl.[29]

Generalization

People tend to seek for patterns in the surrounding world. Pattern recognition and generalization allows them to make predictions, build explanations, and transfer their knowledge to new situations. Nevertheless, humans also have the tendency to overgeneralize learned patterns and rules, using their knowledge about few cases to make hasty conclusions without considering all of the variables that may be involved.[44] People are good at recognizing patterns, but not so good at keeping track of the particular conditions in which such patterns manifest. Stereotyping is a typical example of overgeneralization bias. Novice learners in a field are known to overgeneralize learned rules and principles. For example, chemistry students often think that all chemical compounds are molecular,[45] that all properties of chemical substances follow some type of periodic pattern,[29,32] that all chemical reactions in which acids are involved are acid−base processes,[46] that the octet rule applies to all chemical species under all conditions,[47] or that nucleophiles always attack electrophiles in all reaction mechanisms.[48] Many of these generalizations support one-reason decision making as the analysis of a single feature may be used to reason about many different cases.

Rigidity

When engaged in problem solving, people often tend to fall back on strategies or solutions that have worked for them in the past. In many situations, this approach allows them to quickly come up with an answer, but also can lead to inflexible thinking (e.g., pulling a door marked "push"). This cognitive tendency is known as a mental set. Individuals are also often biased to use objects only in the way and contexts in which they have traditionally used them, failing to make use of such tools in flexible and creative ways in new situations. This cognitive bias is named functional fixedness and, together with mental set, are examples of cognitive rigidity.[49] Novice chemistry students are known to be quite rigid in their approaches to problem solving, applying learned algorithms in rather inflexible ways and being unable to recognize more productive strategies. This inflexibility does not only manifest when solving problems, from general[10] to organic[50] to physical chemistry,[51] but also while building and interpreting different types of chemical representations (e.g., Lewis Structures).[41,52]

AFFECTIVE JUDGMENTS

Overconfidence

Research studies carried out in a variety of contexts show that people's confidence in their judgments and decisions, or in their understanding of a subject, systematically exceeds their actual accuracy.[53] This overconfidence bias seems to be responsible for several cognitive illusions, such as having an" illusion of control" of the situations in which they are involved, or holding an "illusion of explanatory depth" which leads them to believe that they know or understand more than they actually do about the structure and mechanism of systems and devices.[54] These types of illusions are roadblocks for learning because they are likely to stop people from reflecting deeply about a subject. Once students develop a general sense of how a system or phenomenon may work, or develop a sense of how to make it work, they are likely to confuse this superficial knowledge for a deeper understanding of underlying mechanisms. Recent research results in chemistry education suggest that low performing students tend to be overconfident in their knowledge of topics such as stoichiometry[55] or organic acids and bases,[56] and that these types of illusions may be quite difficult to dispel.[57]

Affect

People's judgments and decisions are not only influenced by the information that they can fluently process, but also by the feelings evoked by what they perceive. The positive or negative emotions prompted by words or images affect their judgments regarding benefits, costs, and risks of objects and events, influencing their preferences and choices.[58] For example, if people dread traveling by plane, they will prefer other types of transportation despite actual higher risks. Using readily available affective impressions to make decisions (affect heuristic) can be easier and more efficient than weighing multiple pros and cons, but may also lead to irrational decisions. Existing research suggests that most people have negative feelings toward synthetic substances and toward chemical processes used to transform matter. On the other hand, they have positive feelings toward what they perceive as natural products.[59] Thus, when making or supporting choices in their personal and social lives, individuals are likely to be negatively biased toward chemical products and ignore any evidence that contradicts their emotions. These attitudes and beliefs have been elicited in the reasoning of people from elementary school[60] to college.[61] Recognizing and working with these issues is of critical importance in both formal and informal chemistry education if we aspire to build a more chemically literate society.

FINAL COMMENTS

Intuitive reasoning is governed by cognitive processes that are fast and frugal (Type 1), acting on a basic principle of "satisficing" to generate a response. Satisficing is the idea that when people engage in a cognitive task, such as problem solving, decision making, or sense making, they tend to stop cognitive effort once they find a solution, make a judgment, or build an explanation that is not necessarily optimal, but just good enough to deal with the task at hand.[17,62] That is, the solution minimally satisfies people's goals in a given time and context. The problem with helping students develop meaningful learning about the concepts we value is that the human mind often becomes satisfied with a shallow understanding of most issues. Nevertheless, recognizing and understanding the different heuristics described in the previous sections can help us devise strategies to challenge students' default reasoning approaches and help them to control them.

Many of the heuristics described in this paper act in tandem or conjunction when people face a decision. Task features will activate diverse associations in people's minds (associative activation), some of which will be processed more rapidly than others (fluency), particularly those involving familiar features (recognition), and the final decision will likely be based on just one of the most salient cues (one-reason decision making). The easiness with which a given option may come to mind can be expected to increase confidence in the final choice (overconfidence). This interconnection between cognitive processes makes it difficult to propose targeted strategies to help students control or avoid misapplying each of the 10 heuristics. It would also be naïve, and likely counterproductive, to suggest that we should engage in a frontal fight against all forms of Type 1 reasoning in our classrooms. As previously mentioned, heuristic strategies can be highly productive when applied using the proper cues in the right contexts. From my perspective, effective strategies to help students control heuristic reasoning demand ambitious and coordinated changes in chemistry education; isolated interventions are likely to have little impact. Additional research is needed to explore how and to what extent heuristic reasoning is applied by students in different areas and educational levels, and how it affects their learning.

Simultaneously, we need to use this research to reshape our chemistry curricula, instruction, and assessment to better support the development of productive chemical thinking.[63]

First, we must find ways to help students build a more robust and coherent knowledge structure on which they can rely when making decisions; this will demand a careful reconceptualization of our curricula. In general, we are trying to teach too much content and failing to help students integrate their knowledge. Focusing our efforts on the articulation of learning progressions for core concepts and ideas should become an imperative in chemistry education at all educational levels. Recent work in this area offers curricular alternatives that chemistry educators should consider.[63−65] Second, we need to transform our teaching practices, to more meaningfully engage students with the content and to develop their metacognitive skills. Promising teaching approaches in chemistry seek to involve students in authentic practices in diverse contexts, transforming classrooms into reflective communities of thinking and learning about fundamental and relevant matters.[66,67] Third, we must revise our assessment practices that often reinforce the application of heuristic reasoning by relying on questions and problems that demand mostly low-level thinking..[68] Recent work in chemistry education can help instructors consider multiple dimensions of assessment, moving beyond the mere evaluation of factual content knowledge and algorithmic reasoning.[69] Ultimately, instructors need to reflect on the extent to which their own curricular, instructional, and assessment choices are actually guided by reasoning heuristics that lead to quick, familiar, and one-dimensional solutions that they apply with unwarranted confidence.

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Notes

The authors declare no competing financial interest.

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