Problem-based Learning

Commentary: Brain Respiration Fuels Problem-solving Activity

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The American Chemical Society’s Chemistry in Context initiative targets non-science majors taking a one-semester chemistry course to satisfy a general education science requirement [1]. It generated a curriculum and a textbook now in its sixth edition [2] that addresses major chemistry concepts in the context that students will find relevant to them. When I look through the textbook, I see many things that interest me and think the non-science majors are being introduced to important ideas that science majors should also be learning, but frequently are not.

The very first exercise in the textbook, “Take a Breath,” is a wonderfully simple experiment that students can do individually, but it is better done in groups in a classroom or laboratory setting. Each group receives a Ziploc bag, several straws, and a plastic ruler. They are asked to estimate the volume of air in liters that they breathe each day. This is a problem-solving activity in which students must decide what information they need and how they will get it. Although the bags contain standard volumes, the units are not metric and the volumes are not given to the students. It presumes that students have access to a clock, watch, or other timer that measures time in seconds. To complete the estimation, the students must determine how long it will take to fill the bag breathing normally, estimate the volume of the irregularly shaped filled bag, and then convert those data into the desired units.

If there are several groups, the various estimates can be tallied to see the range of values obtained. These in turn can lead to discussion of experimental design, accuracy of measurements, validity of assumptions, or errors in calculation that groups resolve by comparing their respective procedures. Sooner or later a student may ask, “What is the right answer?” This can lead to further productive discussion about the nature of science.

Although this activity could be used with science majors, it is a bit too simple in terms of the calculations. Consequently, I have modified it and used it as a group examination in a problem-based learning class studying hemoglobin and oxygen transport [3]. The modified version of the activity asks the following: Our brain uses glucose as its sole energy source. Each day a typical adult human brain oxidizes 150 g of glucose to carbon dioxide and water [4]. What percent of the oxygen you inhale each day is used by your brain?

This modification introduces several additional challenges. Students need to know the balanced equation for glucose respiration, the molar volume of a gas, and the proportion of air that is oxygen. They need to assume that the volume of air inhaled is equivalent to that exhaled. As budding scientists, they should consider individual variation and replication of results. For small groups of three or four, the activity and follow-up discussion can take most of a 50 min class period.

Observing how students react to this activity reveals how students think and the deficiencies in our education of them. Many students feel uncomfortable with the problem because they feel it provides insufficient information, which is true, but it is information that should be part of their general knowledge—something they must bring to the problem. The second difficulty is that few students really appreciate that estimation doesn’t require an exact calculation. They feel obligated to produce values with three or more unwarranted significant figures on a calculator when they could quickly work at the level of one or possibly two significant figures with a pencil and paper or in their heads.

There are several ways to approach the problem and there is no algorithmic equation to use. Such uncertainty proves rather stressful and unsettling to some students who are used to having a procedure to follow and an equation to apply. When they get an answer, they frequently lack confidence in it and need verification that they have done things properly. The fact that there is a range of reasonable answers that is contrary to their problem-solving experiences in typical science classes.

Please note that I have deliberately not indicated a reasonable range of estimates for this problem. Hopefully that will not frustrate readers of this column.

REFERENCES


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