Flipping the question: Using student-constructed questions to uncover misconceptions.

Abstract:

An activity for reviewing the content of a high school, honors chemistry curriculum with an eye toward standardized test preparation is presented. In the activity, students create assessment items from provided answers, or question stems. In doing so, students consider the structure and style of standardized test questions while also being provided with a forum for demonstrating misconceptions that they hold on a variety of topics within the larger chemistry curriculum. Strategies for confronting student misconceptions are also discussed.

Introduction:

Uncovering student misconceptions related to scientific concepts and practices remains a major area of the science teacher's job. A well-established body of research exists on the role of uncovering misconceptions as a means to their rectification (see National Research Council, 1997). A variety of approaches can be employed to facilitate this process. This paper describes a technique for uncovering student-held misconceptions in a high-school honor's level chemistry course through the use of "Flipped Questions", an activity wherein students are required to construct questions that are acceptable for a provided bank of answers (for multiple-choice items), or a provided prompt (for constructed response items). Through constrained question-answer construction, teachers are able to provide their students with an opportunity to demonstrate the level of development of their thinking on a variety of topics, and allow for a more creative mode of reviewing content than might otherwise be employed.

Overview:

The inspiration for this activity was taken directly from several resources that were uncovered through informal research on ways to improve exam review. The author has found that many times review for exams relies heavily on rote test training, and other similar activities. While these may have utility for students, they are not particularly interesting, and they do not provide students with the opportunity to engage with content from any place other than one of knowledge acquisition and recapitulation. A major source of inspiration was an edutopia article written by Matt Levinson and his explicit suggestion to "Flip the question". Levinson suggests that by having students determine the questions for answers, they will be able to find patterns in the answers that focus their attention on the important, overarching concepts in the questions. What follows is a formalized implementation of this structure within a New York State, Honors Chemistry course that terminates in the Regents exam.

Methodology:

A review activity comprising a selection of assessment items was generated. While there are many tools that can allow similar types of materials to be created, the author found the Problem-Attic website to be particularly user-friendly, and free of charge. The website generates .pdf files of selected regents assessment items. In addition to items from the New York State Regents exams, Problem-Attic also contains items from other state assessments, the NAEP and TIMSS exams, and Common Core assessments for a variety of subjects other than chemistry. Following their creation, the stem of all multiple-choice items, and the questions from all constructed response items were removed from the document. This can be accomplished in a variety of ways, but the author found the online, .pdf markup tool at PDFescape, which has a "whiteout" option, to be the easiest digital way to accomplish this task. After creating the problem sets, they were assigned to students. The guidelines for these assignments stated that students were to use the provided information to create "regents-level questions" and indicate the correct answers for those questions.

Results:

Several samples of student work are shown in the following figures. For the purpose of this discussion, only question-answer pairing that demonstrate misconceptions are shown. In Figure 1a, the student has written a constructed-response question that confuses conceptions of radioactive stability with conceptions related to chemical stability. In Figure 2a, the student has written a multiple-choice item and indicated an answer that indicates that the student has a fundamental misconception about the nature of energy in chemical reactions. Figure 3a demonstrates a misconception related to stoichiometric concepts, apparently having confused the equivalency that 1 mole of any gas at STP occupies a volume of 22.4 Liters for its inverse.

For the sake of comparison, the original Regents exam items that were used to create these questions are provided for each item (Figure 1b, 2b, and 3b).

Discussion:

In creating this assignment, the expectation was that it would provide students with a different review structure that would be useful simply for the fact that it was a different way to review. However, it soon became apparent that this activity was useful in a way that was not anticipated: The structure provided a ready forum for students to demonstrate a variety of misconceptions that they hold on the content of the course. The professional literature on uncovering and mitigating student misconceptions is vast, and there is widespread consensus that it is important to provide learners with a forum by which they can evoke their pre-conceptions prior to being able to effectively evoke conceptual changes. The flipped question activity provides instructors with one such forum, in a style that is relatively easy to employ within the structures of a traditional science classroom.

Of course, evoking existing conceptions is only the initial step in a larger process of having learners make meaning of the material in a course of study. To that end, once it became apparent that learners were demonstrating their misconceptions when engaged in flipped question activities, the guidelines of the activity were extended to continue the process of confronting and rectifying misconceptions. Learners were presented with an opportunity to revise any items that were identified as being "incorrect" (defined as a question-answer pairing that was not valid). To recoup lost points on the assignment, learners had to revise the original question-answer pairing to one that was valid, and compose a brief statement as to why their original pairing was not correct. In this way, learners were encouraged to revisit their original work and consider why it was not valid.

Several other revisions to the original assignment were also implemented after the initial administration. To remedy issues of students writing overly simplistic question-answer pairings, students were informed that any question deemed to be "too easy" (defined as being below the level of a typical Regents question) would be considered incorrect. Additionally, to increase meta-cognitive aspects of the assignment, students were asked to indicate the question-answer pairing that they felt was the easiest and the hardest among the items that they had constructed.

It is interesting to compare the original Regents items to the ones that students have created. In each case, there is a striking similarity between the student-constructed item and the original version. Another possible extension activity could involve having students make this comparison. This approach could provide instructors with another avenue to have students examine their conception of a topic in light of the "correct" version of the question as shown on the exam.

Concluding Remarks:

For better or worse, review for end-of-course assessments is an unavoidable aspect of most public school science curricula. There are a variety of approaches that can be employed by instructors when engaged in this process. The most fruitful approaches will employ a variety of techniques that help students to understand their thinking about the material of a course, and help them to become familiar with the assessment tool that they will need to use. The Flipped Question structure is one such tool that can be used. While requiring that students think about the style and structure of the exam, it also requires students to consider the material of the course, and the ways in which their understanding can be assessed within particular testing structures. Students are provided with a forum to demonstrate the extent of their learning, and also possible misconceptions that they might hold related to the material of the course. In uncovering student misconceptions, a structure like the Flipped Question activity can facilitate the kind of reconsideration and revision that a learner will need to undertake if they are ever going to be able to correct their misunderstandings related to a body of knowledge.

Resources:

The following websites were utilized in this activity:

PDFescape: http://www.pdfescape.com - a free online tool for the markup of .pdf documents.

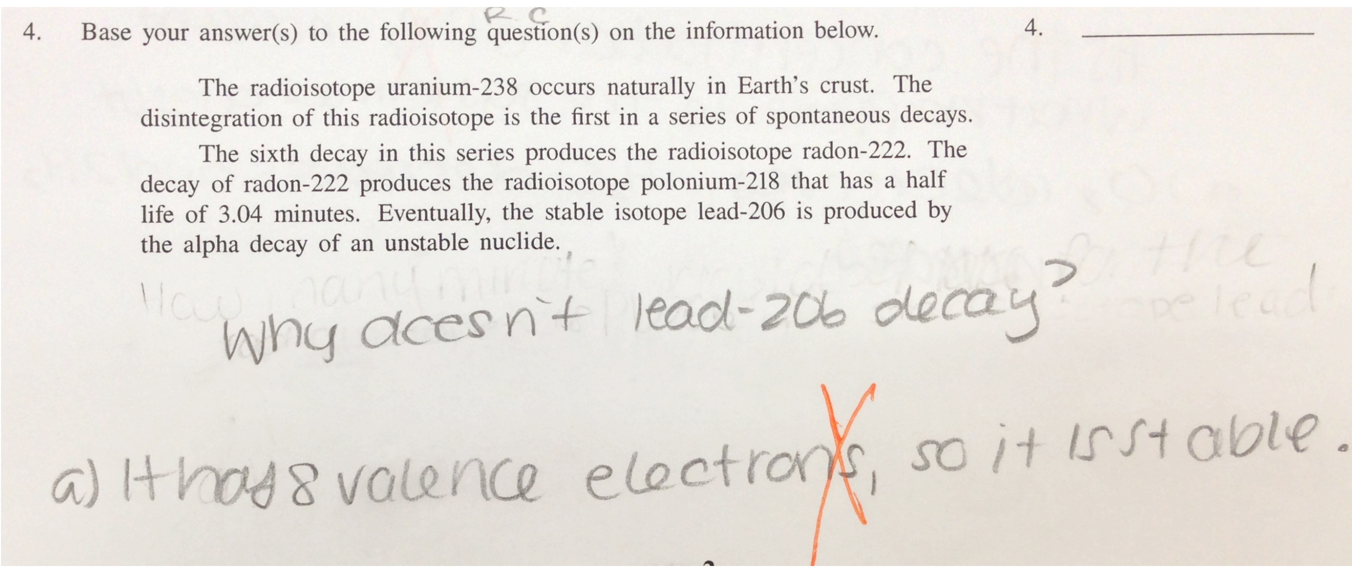
Problem-Attic: http://www.problem-attic.com/ - a free online repository of assessment items.

References:

Levinson, M. (2013, March 15). [Web log message]. Retrieved from http://www.edutopia.org/blog/play-with-standardized-test-prep-matt-levinson

National Research Council. (1997). *Science teaching reconsidered: A handbook*. (p. Chapter 4). Washington, D.C.: The National Academies Press. Retrieved from http://www.nap.edu/openbook.php?record_id=5287&page=27

Figures:



4. Base your answer(s) to the following question(s) on the information below. 4. ____________

The radioisotope uranium-238 occurs naturally in Earth's crust. The disintegration of this radioisotope is the first in a series of spontaneous decays.

The sixth decay in this series produces the radioisotope radon-222. The decay of radon-222 produces the radioisotope polonium-218 that has a half life of 3.04 minutes. Eventually, the stable isotope lead-206 is produced by the alpha decay of an unstable nuclide.

Why doesn't lead-206 decay?

a) It has 8 valence electrons, so it is stable.

Figure 1a: Student-constructed question demonstrating confusion related to conceptions of radioactive stability and chemical reactivity.

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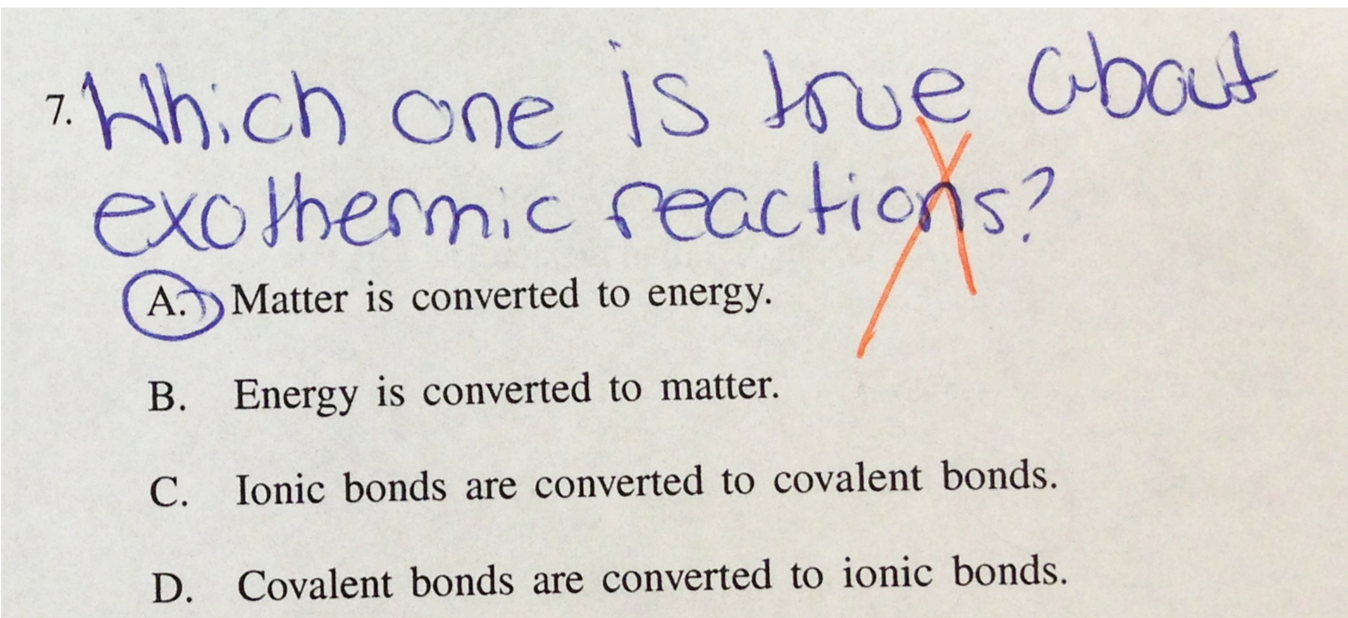
79 Explain, in terms of electron configuration, why atoms of the radioisotope produced by the sixth decay in the U-238 disintegration series do not readily react to form compounds. [1]

80 Complete the nuclear equation *in your answer booklet* for the decay of the unstable nuclide that produces Pb-206, by writing a notation for the missing nuclide. [1]

81 Determine the original mass of a sample of Po-218, if 0.50 milligram of the sample remains unchanged after 12.16 minutes. [1]

Figure 1b: The original item series using this prompt from the August, 2010 Chemistry Regents Exam.



7. Which one is true about exothermic reactions?

A. Matter is converted to energy.

B. Energy is converted to matter.

C. Ionic bonds are converted to covalent bonds.

D. Covalent bonds are converted to ionic bonds.

Figure 2a: Student-constructed question demonstrating a misconception about the nature of energy transformation in chemical reactions.

30 Which change takes place in a nuclear fusion reaction?

(1) Matter is converted to energy.
(2) Energy is converted to matter.
(3) Ionic bonds are converted to covalent bonds.
(4) Covalent bonds are converted to ionic bonds.

Figure 2b: The original multiple-choice item from the January, 2005 Regents exam.

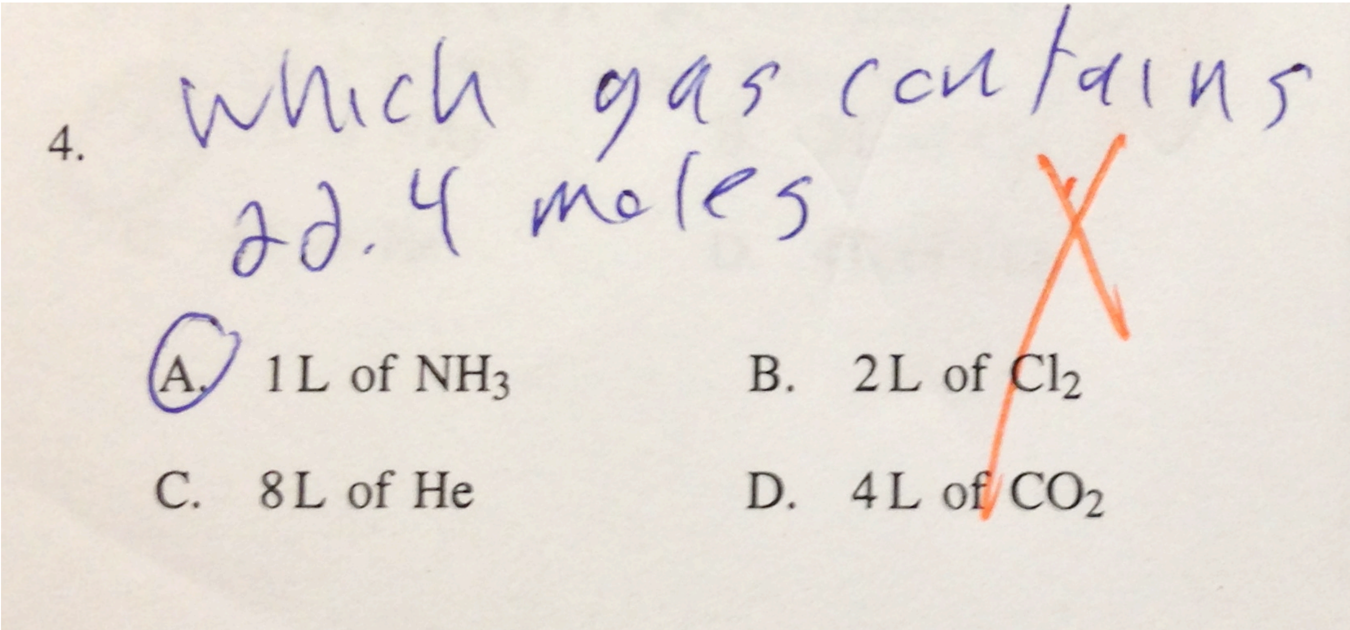


Figure 3a: Student-constructed question demonstrating a stoichiometric misconception related to volume and number of particles of a gas.

19 At STP, 4 liters of O_2 contains the same total number of molecules as

(1) 1 L of NH_3 (3) 8 L of He

(2) 2 L of Cl_2 (4) 4 L of CO_2

Figure 3b: The original multiple-choice item from the January, 2005 Regents exam.